SCIENCE PRIMERS, *edited by*
Professors HUXLEY, ROSCOE *and*
BALFOUR STEWART

BOTANY

SIR J. D. HOOKER C.B. P.R.S.

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J. D. HOOKER, C.B., F.R.S.

WITH ILLUSTRATIONS.

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PREFACE.

THE object of this Primer is to supply an elementary knowledge of the principal facts of plant-life, together with the means of training beginners in the way to observe plants methodically and accurately; and in the way to apply the knowledge thus obtained to the methodical study of Botany.

It is hoped that by its means the teacher may convey a sound elementary knowledge of the number, nature, relative positions and uses of the principal organs of plants, of the order and way in which they grow, and in which plants multiply, and of those resemblances which exist amongst them, by a comparison of which their true relationships are known and themselves classified.

In using this Primer the plants indicated are, whenever possible, to be put into each pupil's hand. Hence, to facilitate its use, I have placed at the end an Index of the plants referred to in it. Most of these may be procured in the country, or from any intelligent nurseryman. Many of them should be grown in every school-garden, and arranged in it systematically, so that the teacher may have the same means of displaying to his pupils the principles of classification that the great founder of the natural classification of plants, Bernard de Jussieu, had after he had thus

arranged the Garden of the Palace of Trianon after its establishment by Louis XV.

The teacher should further have a copious supply of dried flowers, and other parts of these plants so preserved as that the pupil can, after moistening them in warm water, separate their organs. Much may thus be learnt when fresh plants cannot be obtained, and a rehearsal of the summer's lessons upon such dried specimens is a most improving exercise. He should also have a supply of preserved fruits, seeds, sections of stems, and of mounted preparations of the tissues and minute parts of plants adapted for exhibition under the microscope.

Each pupil should have a pocket lens magnifying three or four times, a sharp penknife, and a pair of forceps; and he should be taught to preserve between sheets of paper the specimens he has examined, with a descriptive ticket attached; and also be exercised in the habitual use of the schedules described at pp. 123, 124. For further instructions on these heads see Sect. XXVII. (p. 116).

In using the Primer the pupil should be taught first, the contents of Sections I. and II.; after which he may either take the other sections in order, or go on to Section VI., taking Sections III. to V. afterwards. Sections XIX. and XXV. are too difficult for beginners.

After mastering its contents the pupil may proceed to the use of Professor Oliver's "Lessons in Elementary Botany," which goes over the same ground in more detail.

CONTENTS.

LIST OF ILLUSTRATIONS.

SCIENCE PRIMERS.

BOTANY.

I.—INTRODUCTORY.

THE study of botany is best commenced with the careful observation of the different parts of living plants, their positions and arrangement in reference to one another, the order in which they make their appearance, and their uses to the plant itself. It is hence often called a science of observation, in contrast to chemistry and other subjects of which the study must necessarily commence with experiment. But botany has also to be pursued as an experimental science; only the experiments by which the growth of plants, their modes of living and multiplying, and their relations to the air and soil are investigated, cannot be conducted until much has been learnt by observation alone. Such experiments require also for the most part a previous knowledge of chemistry and physics; those, however, described in this primer will need no more knowledge of these subjects than is to be found in the primers devoted to them.

Plants are living things; they form the **vegetable kingdom** as animals form the animal kingdom. Like animals, plants pass through the stages of infancy and maturity, terminating in death; they also feed, grow, and multiply. Unlike the higher animals, during the ordinary processes of growth (with the exception of germination and flowering) their temperature is not higher than that of the air or water in which they live.

Duration of plant-life.—Some plants have limited lives, flowering but once and dying soon after; others have unlimited lives, throughout which they flower periodically. Plants with limited lives are: 1. **annuals**, which live but for one year or season, as wheat, peas, &c.; 2. **biennials**, which usually flower and die the second season, as the cabbage, turnip, foxglove, &c.; and 3. plants which grow for many years without flowering (for example many palms), flower but once, and then die. Those with unlimited lives are **perennials**, and may be either trees and shrubs which, like the oak and hawthorn, have stems and branches increasing in size from year to year; or herbs like the primrose and snowdrop, having underground stems which annually send up leaves or branches that die off in the same year.

Distribution of plants.—Plants are found on nearly all parts of the surface of the globe, but no two countries have all their plants alike. They are found in the greatest luxuriance and variety in hot and damp climates. They are not found in the very coldest or very driest regions, nor at very great depths in lakes, or the ocean. As a rule, they diminish in size, as well as in number of kinds in proceeding from the tropics to the frigid zones; as regards size there

are exceptions, as the gum-trees of South Australia and the Wellingtonia of California, which are amongst the most gigantic of known plants; the seaweeds of cold seas are also far more bulky than those of tropical regions.

Besides the plants now growing upon the surface of the earth, the remains of many others that are no longer living anywhere, are found in rocks at various depths beneath it. Of these, those that lived most recently and are hence found in the more newly formed rocks, are like existing plants; those that lived longer ago are less like existing ones, and are sometimes very different looking indeed. In short, the longer ago the plants lived the less like they were to plants now living: but however different are the plants that lived longest ago, they all seem to have grown much in the same way, to have depended on similar conditions of light, heat, and moisture, and to have followed the same general course of life.

The forms of plants are infinitely varied. As trees, shrubs, herbs, grasses, ferns, &c., they are familiar to all; but only a small proportion of the vegetable kingdom consists of such plants. The bright green covering of banks, tree-trunks, damp walls, and cottage roofs, and the carpeting of forests and wooded valleys, chiefly consist of mosses and moss-like plants, of which several hundred kinds grow in Britain alone. The ocean's surface sometimes swarms with extremely minute plants, to such an extent as to give the water a distinct colour; and its shores between the tidal levels and below them are covered like meadows with sea-plants of many forms and colours. As green and purple slimes, plants also stain damp

walls, and the rocks and stones in the bottom of fresh-water streams and along the seashore; as leathery or powdery crusts they cling to the hardest rocks and stoniest soils of mountains and moorlands; as moulds they spoil articles of food, books, leather-work, woollen and other fabrics; as dry-rot, and under many other forms, they utterly destroy trees, wooden houses and ships; as smut, rust, bunt, potato- and vine-blight, they prey upon the living tubers, stems, leaves, and fruits of the most valuable crops, and some even invade the organs of living animals.

Things necessary to the life of plants are air, heat above the freezing point, light, water, and earthy (inorganic) matter in some shape. The exceptions to these requirements are few; amongst them are the red-snow plant, a most minute vegetable, which tinges the surface of melting snow with a rosy hue; and fungi, of which some grow or are cultivated in total darkness. No plants, except these last, continue to live in health in the absence of light, as a few blind animals can do (fishes and insects) which inhabit caves, as well as many deep-sea animals, and those that live in the interior of others.

The division of labour in plants.—During their life-time plants perform various kinds of work which are essential, some to sustain them in life and health, others to reproduce their kind. These kinds of work being very different from one another are not accomplished by any portion of the plant indiscriminately, but are carried on by particular parts specially adapted for their special purpose (called **organs**).

In the case of flowering plants, for example, the ·cipal organs are, *a.* The **root**, by which the

plant is fixed to the ground, and absorbs water from it; *b.* The **stem,** which supports the leaves, flowers, and fruit; *c.* The **leaves,** which are usually thin and so placed as to receive as much light as possible upon one surface; *d.* The assemblage of organs called the **flower**; *e.* That part of the flower which grows into the **fruit** containing the **seeds.**

The purposes which organs are specially fitted to serve are called their **functions.** The most important of these in all plants are nourishment and reproduction. All but some of the very smallest plants are without organs of locomotion.

Flowering plants are **nourished** by means of the root and leaves. Unlike animals, such plants have no special stomach to receive the food, no heart or blood-vessels to distribute it, and no special organs to carry off what is not used as nutriment.

The **food** of plants is liquid and gaseous, never solid. The root absorbs water, in which both gaseous and mineral matters are dissolved; and this fluid ascends to the parts of the plant above ground, and so enters the leaves, which also take in carbonic acid gas from the air. By the action of light on the water and carbonic acid in the leaves a substance called **starch** is formed, which is in its turn distributed throughout the plant, supplying in great measure the material for adding to its parts.

The excess of water taken up by the root is exhaled by the leaves, and this tends to keep them cool. From the starch produced in the leaves and nitrogenous compounds taken up by the roots and dissolved in the fluids which permeate the plant, **albuminoids**

are formed, which are very essential in producing growth.

The reproduction of flowering plants takes place in two ways. First, and principally, by seeds; secondly, by buds that separate and grow into independent plants. Seeds are produced by the interaction of special organs of two kinds, and are inclosed in a covering called the fruit. Buds that separate themselves and become new plants are formed on various parts of plants, as where the leaf is attached to the stem in the tiger-lily and the tubers or underground branches in the potato plant.

Many plants may be artificially multiplied by division; that is, by cutting off a twig with a bud on it, and sticking it into damp ground, when the twig will send forth roots. Or the twig may be inserted (grafted) into a slit in the branch of a similar tree, with which it will unite, and the bud thus nourished will grow, and produce leaves, flowers, and fruits.

The tissues of plants.—The substance of plants is not made up of particles in which no definite form or structure is visible, but consists of minute bags called cells, and of tubes called vessels (which also consist at first of rows of cells), packed more or less closely together.

The chemical constituents of plants.—Plants, like animals, contain a far greater weight of water than of anything else. Besides the elements of water (oxygen and hydrogen), the tissues contain carbon (which is charcoal), and more or less nitrogen. Plants obtain the water principally by their roots; the carbon by their leaves from the carbonic acid gas absorbed from the air, and

the nitrogen in solution by the roots, from salts of ammonia (or nitrates). Plants contain moreover varying quantities of mineral substances, also absorbed in solution by the roots. These remain as a white ash when plants are thoroughly burnt.

The green colour which prevails amongst plants depends on the presence of a peculiar matter (**chlorophyll**) within the cells, especially those near the surface of the plant. This matter becomes green only under the action of light, consequently plants grown in quite dark places are never green, nor are those parts of them which are not exposed to the light (such as the roots).

The primary divisions of plants.—Plants do not present a disorderly mass of living things, having no degrees of relationship one with another, like children's letters or numerals emptied out of a box; nor are they related to one another equally, differing in similar degrees, as one does from two, two from three, &c.; but they fall into groups variously related to one another, some like brothers, others like cousins, and so forth; whence arises the classification of the vegetable kingdom into sub-kingdoms, classes, orders, genera, and species.

There are two primary groups, or sub-kingdoms of plants; the **flowering** and the **flowerless**, which differ very much indeed; the flowering having, amongst other characters, usually very conspicuous structures commonly known as flowers, which produce seeds; and these seeds invariably contain an independent plantlet (embryo). The flowerless plants (ferns, mosses, seaweeds, &c.) have no such flowers, nor such seeds: instead of seeds they have spores which contain no plantlet.

Plants purify the air that is being habitually rendered unfit to breathe by animals having already breathed it. They provide the animal kingdom with food, and often with shelter. They protect the surface of the earth from being too much scorched by the sun's rays by day, and too rapidly cooled by radiation at night. They prevent the too rapid evaporation of the rain-fall; and they supply man with food, fuel, medicine, and many materials for arts and manufactures.

II. GENERAL CHARACTERS OF FLOWERING PLANTS.

1. The vegetable kingdom as stated above presents two quite distinct sub-kingdoms, which the most superficial observer rarely confounds: that of flowering plants, to which trees, shrubs, and herbs belong; and flowerless plants, such as ferns, mosses, seaweeds, lichens, and fungi.

The pupil is recommended to begin with the flowering plants, not only because the two sub-kingdoms are so different that they cannot be studied together advantageously by a beginner in botany, but because most of the flowerless plants require for their study high magnifying powers of the microscope and skill in using them.

2. Flowering plants present the following organs or parts: **root, stem, leaves, flowers,** which latter are succeeded by **fruit,** containing **seed.** Most flowering plants have roots; all have stems,

though these may be reduced to a mere knob on the top of the root: some few have no leaves, as the dodder, and plants which, like it, feed on the juices of others: many never have but one axis, which eventually terminates in a flower: but all must have a flower or flowers, though these may be of a very simple nature.

3. The organs of flowering plants may be classed according to their relation to one another under two divisions: (*a*) an **axis**, of which the root is the descending and the stem the ascending part; and (*b*) **appendages of the axis** or foliar organs, which are the leaves, and the parts of the flowers.

4. They may also be classed according to their uses (functions) as follows: (*a*) for **support**, the root and stem; (*b*) for **nourishment**, the root and leaves; (*c*) for **reproduction**, buds that separate from the plant, flowers, fruit, and seeds.

This division is evidently a very rough one; for while the root is often the sole organ of support, fixing the plant to the ground and holding it upright, other plants are supported wholly or in part by their twining stems (convolvulus), by tendrils (vine), by twisting leaf-stalks (clematis, fumaria) and even flower-stalks, by hooked prickles (brambles), by sticky glands, and in the case of water-plants by floats containing air.

The root and its divisions are the organs of absorption; the leaves of transpiration and assimilation, but all green parts of the plant are so to some extent.

The seeds are the principal means of reproducing plants, but, as already pointed out, this process is

also often effected by bulbs that separate themselves (tiger-lily); or by the budding of underground bulbs (onion); or by tubers covered with buds (potato); or by prostrate rooting stems (bramble).

III.—THE TISSUES OF PLANTS.

5. The substance or material of which a plant consists is called its tissue; and there are several kinds of tissues. Their nature cannot be made out without a microscope; but as a low power will show the most important of them, these should be learned at once.

6. The chief is **parenchyma** (cellular tissue),

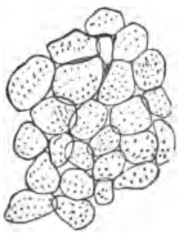

FIG. 1.—Parenchyma of rounded cells, many times the real size.

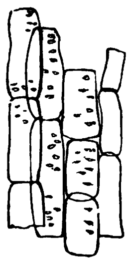

FIG. 2.—Parenchyma of rather long cells, many times the real size.

which forms the principal substance of most plants. It consists of minute rounded sacs, called cells, crowded together and often becoming angular by pressure (Figs. 1 and 2). Orange-pulp is an example of cells originally separate and afterwards packed closely, but easily separable; cork and elder pith of cells adhering by their sides. The walls of the sac

consist usually of a very thin and transparent membrane, which may contain air only, when the cells are dead (as in old pith); or a fluid, as in the cells of orange-pulp; or, besides fluid, granules of protoplasm (Par. 11), coloured by substances which are green in leaves, and of other tints in many flowers; or granules of starch. Sometimes the cell-wall is very thick and hard, as in the stone of the cherry and other stone-fruits, and the leathery surface of leaves such as those of the stone-pine (Fig. 3). Almost all plants have

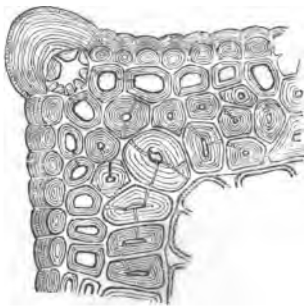

FIG. 3.—Long thick-walled cells from a leaf of stone-pine as seen in a cross-cut, many times the real size.

more parenchyma than any other tissue. Fluids can pass through the walls of cells, and nutritious matters in the fluid state are distributed through the plant, by passing from cell to cell. The water, however, which is taken up by the roots and is given off by the leaves chiefly permeates the walls of the cells (especially those of the wood, Par. 7), and so may pass from one to another without entering their cavities. The layer cells which cover the surfaces of the plant are a good

deal flattened, are accurately fitted together, have no coloured contents, and form the **epidermis.**

7. **Wood-tissue,** of which in addition to vessels wood is principally formed, consists of long cells, or rather tubes, closed and tapering at both ends, with thick walls, and which lie side by side and form wood.

8. **Bast-tissue** consists of very long flexible cells, or rather tubes, also closed at both ends. It occurs in the inner bark, and supplies the material of many useful fabrics. Hemp and flax are bast-cells of the plants of those names; and the bast used by gardeners for tying is the inner bark of the lime-tree.

9. **Vascular-tissue** consists of long unbranched tubes (vessels), with thin walls, which are often dotted or barred, and sometimes thickened internally by spiral threads, easily seen in the leaf of the hyacinth, if

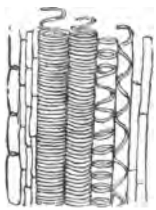

FIG. 4.—Spiral-vessels with cellular tissue on each side, many times the real size.

broken across. These tubes are called spiral vessels (Fig. 4). All such tubes are formed from rows of superposed cells, the partitions which separate them having been absorbed.

The tissues 7, 8, and 9 usually occur together in the

form of bundles which traverse the parenchyma, as the veins (or nerves) of the leaves, and are called **fibro-vascular bundles.**

IV.—THE NATURE OF THE CELL, AND GROWTH OF CELL-TISSUE.

10. To understand how plants grow, and how such products as sugar, starch, oils, and resins are formed in them, it is necessary to examine further cellular tissue; for it is by the addition of cell to cell that plants grow, and by chemical changes taking place within the cell, that the above-named and other substances are formed.

11. The cell consists of a membrane (**cell-wall**) and its contents (**cell-contents**). The cell-wall is a thin (rarely thick) transparent bag of *dead matter* called **cellulose.** This bag contains when young a viscid granular substance *endowed with life* and sometimes exhibiting motion, called **protoplasm.** Cellulose is composed of oxygen, hydrogen, and carbon; protoplasm of these together with nitrogen and sulphur.

12. When cells are very young they are smaller in size, the cell-wall is thinner, and they are completely filled with the protoplasm; a darker rounded portion of this is generally to be noticed in them and is called the **nucleus.** As the cells grow in size their cavity becomes larger than the mass of protoplasm which originally filled it. The cell-wall is always lined by a layer of protoplasm, but in the interior of the cell cavities are formed in the protoplasm which are filled with a watery fluid called the cell-sap. At a later period, the protoplasm is reduced to a thin

film, in which the nucleus is placed and which lines the cell-wall; strings of protoplasm pass often from the nucleus across the cell-cavity. In old wood and cork cells the protoplasm has completely disappeared, and the cavity of the cell contains nothing but water or air.

The great importance of the nitrogenous substance protoplasm, as the only living matter which the plant contains, cannot be too firmly insisted upon. It is of the same nature as the protoplasm of which some of the lowest animals (those nearest the plants) wholly consist, and which forms the living substance of the bodies of the higher animals, including man himself.

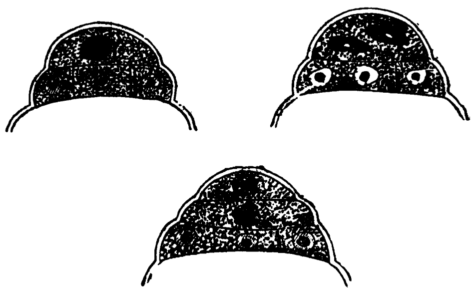

FIG. 5.—Growing point of stem of stone-wort (chara) showing formation of new cells by division, many times the real size.

13. New cells are formed by the protoplasm of some cells when still quite young dividing into halves, between which a wall of cellulose is then formed. The original cell-cavity is thus divided into two. This

breaking up of the protoplasm commences by the division of the nucleus (Par. 12) seen in the protoplasm of most cells, and the protoplasm collects round each half of the nucleus.

14. The rate at which cells thus multiply is astonishing, and is most conspicuous in mushrooms, toadstools, &c., which contain no fibrous or vascular tissue. The giant puff-ball grows very rapidly from the size of a marble to that of a child's head, by the growth and increase of cells, which individually are but a few thousandths of an inch in diameter, and of which three millions are estimated to be formed in twenty-four hours.

15. Cells which have ceased to divide gradually grow into their permanent form, which in various cases is very different.

(*a*) Those which form cork and pith do not alter very much in shape, and, finally losing their protoplasm and cell-contents which are absorbed into more active adjacent cells, simply contain air.

(*b*) Wood and bast cells grow very much in length. The protoplasm continues to secrete cellulose, which is added (interstitially) to the cell-wall and gradually makes it very thick (see Par. 6). These, too, lose eventually their living contents and contain only air or water. Other cells may have their walls thickened in the same way without becoming elongated. Vessels (Par. 9) are formed by the partitions between rows of superposed cells becoming absorbed.

(*c*) In many cases the protoplasm, instead of secreting material which is added to the cell-wall, forms various substances out of the fluids which permeate through the cell-wall and mix with the cell-sap.

These are imbedded in the protoplasm, as in the case of starch grains, oily and fatty matters or grains of albuminoids; or they are dissolved in the cell-sap, as in the case of sugar and the substances (alkaloids, &c.) which give so many plants useful or noxious properties. The wax which forms the *bloom* on the surface of many plants exudes through the cell-wall from the interior of the cell-wall where it is formed.

(*d*) The above-mentioned substances often seem to fill the cell-cavity to the exclusion of everything else, but the remains of the protoplasm can generally still be traced, though in a very shrivelled state.

(*e*) In the green parts of plants the protoplasm undergoes a peculiar change by which part of it is broken up into granules which contain the green colouring matter (chlorophyll). These granules are accordingly termed **chlorophyll granules.**

16. Chlorophyll granules consist of protoplasm coloured green by a pigment called chlorophyll. They abound in the superficial cells of plants, and, their colour being seen through the thin cell-walls, give the green hue to leaves; similar granules tinged with other colours give in some cases the bright tints to flowers. Chlorophyll under the influence of sunlight brings about changes in the cells of the leaf that result in starch being formed and distributed all through the plant as required. In so doing, it is supposed that the chlorophyll separates the carbon from carbonic acid taken from the air, gives back the oxygen to the air and supplies the carbon (which at the same time combines with the oxygen and hydrogen of water to form starch) to the plant. It is a curious fact that chlorophyll is not developed,

and therefore that this process will not go on, except the plant be supplied with iron; and as all soils contain iron the plant can always take this substance up in solution by its roots. In the absence of sunlight also, the green colour of chlorophyll does not appear; thus, the effect of earthing up celery is to make it white, its exposed parts being very green.

17. **Starch.**—This compound of carbon, hydrogen and oxygen abounds within the cells of many parts of various plants, as in the potato and all cereal grains: and is the principal constituent of arrowroot, tapioca, sago, &c. It consists of white granules, differing in form in different plants (Fig. 6), often

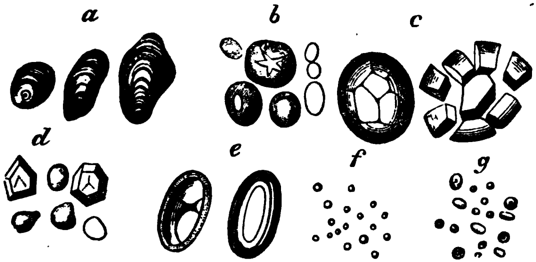

FIG. 6.—Starch. Granules from *a* potato, *b* wheat, *c* oats, *d* maize and rice, *e* bean and pea, *f* parsnip, *g* beet; all very many times their real size.

marked with concentric rings, and it is tinged blue by iodine. It is found in greatest quantity in the parts of plants intended to contain during winter deposits of food for the growth of the plant in the following spring. The starch which the cells of seeds and roots contain is used up in the growth of the structures which these give rise to.

V.—THE FOOD OF PLANTS.

ABSORPTION, TRANSPIRATION, ASSIMILATION.

23. The food of plants is partly gaseous and partly liquid; and is derived from the earth or water in which they grow, and from the air. The liquid food is taken into the plants chiefly by their roots, the gaseous chiefly by their leaves.

24. The **gaseous food** of plants consists of carbonic acid gas supplied chiefly by the atmosphere. The **liquid food** is water, in which various saline substances are dissolved, the principal components of these being nitrogen, phosphorus, sulphur, potash, and iron. The above-named matters are found in most soils in which plants grow, but cannot be taken up by the roots except they be dissolved in water.

25. **Absorption.**—The liquid absorbed by the roots, consisting of water and substances dissolved in it (called **sap**), ascends through the stem and branches and so reaches the cells of the leaves, or the cells near the surface of plants that have no leaves. In mounting up it passes both from cell to cell through their walls and along some of the tubes of the vascular tissue. But a good deal of the water passes through the substance of the cell-walls without entering their cavities.

The taking in of carbonic acid gas from the air is another process of absorption. It is performed by the leaves, in the cells of which a chemical process goes on under sunlight, by which the carbonic acid is broken up, the carbon being retained by the plant, and the oxygen given back to the air.

26. **Transpiration.**—The sap on reaching those surfaces of plants that are exposed to the light, parts with a great deal of its water as vapour, both through minute pores in the leaves and elsewhere, as well as through the walls of the superficial cells. These pores are called **stomates** (Par. 72); they exist in very great numbers, chiefly on the underside of the leaves: an apple-leaf presents upwards of 100,000 of them. This process, called transpiration, keeps plants cool in the hottest weather, and is so rapid that a sunflower plant has been found to give off a quart of fluid in twenty-four hours, and an oak or beech-tree must give off many gallons in the same space of time.

27. **Assimilation.**—The process by which the carbonic acid absorbed by the leaves and the water absorbed by the roots are combined together in the leaves under the influence of sunlight to form starch, free oxygen being at the same time given off, is called assimilation. The starch so formed appears to be dissolved in the cell-sap during darkness, and to be distributed from cell to cell all over the plant. It is used up wherever growth is taking place, furnishing the material for the formation of the cellulose of the new cell-walls, or it is stored up again in the solid form, as a reserve of material for future use, as in seeds. Besides conversion into cellulose, starch is capable of being transformed under the influence of protoplasm (Par. 11) into oily and fatty matters, and also into sugar.

The soluble starch in its downward passage through the tissues of the stem, meets with various saline matters containing nitrogen, such as nitrates or salts of ammonia. From these in some way or other not

yet understood, but under the influence of protoplasm, the nitrogen is abstracted, and from this, together with sulphur (Par. 22) and the constituents of starch albuminoids are manufactured.

These albuminoids are the necessary food of protoplasm. It is important to remember that their formation depends upon the manufacture of starch in the green parts of plants and this depends upon exposure to sun-light. We see, therefore, why without light plants starve; their protoplasm ceases to be nourished.

28. Like animals, plants cannot live without oxygen. The activity of the protoplasm in both cannot be kept up without it. The protoplasm of all living things wastes and would die altogether unless it were nourished. This process of nourishing involves **respiration**, *i.e.* getting rid of superfluous carbon, which combines with oxygen taken in from the air, and is given off as carbonic acid (Par. 158).

29. The effect of plants requiring mineral substances for their nourishment is, that one kind of crop cannot be grown continuously on the same piece of ground, if it is periodically cut and carried away. This has led to the use of manures containing the substances taken away in the crop, for rendering the exhausted soil fit for another crop of the same kind. In a state of nature, on the contrary, the plants of each piece of ground die where they grow, and by decay give back to the soil what they took from it.

30. The above-mentioned plant-foods are all inorganic substances; and until quite recently plants (except fungi and parasites) have been supposed to be incapable of deriving nourishment from organic sub-

stances, except these be completely decayed. It is now, however, ascertained that some plants can derive nourishment from raw meat, insects, and other animal and even vegetable matter, these plants being provided with organs for the purpose of digesting such matters. The leaves of the nepenthes, side-saddle flower, Venus's fly-trap, and sundew, are instances. In all these cases when the meat is laid on the digesting surface, a fluid is poured out from its cells which acts as a solvent on the animal substance, enabling the plant to absorb it and use it for its nourishment.

31. Except in cases of accident, plants in a state of nature either die a natural death, that is, one that comes after the functions of all its organs have been fulfilled, or are eaten by animals. Those that die a natural death undergo chemical changes which constitute decay, and in so doing return to the air and earth the materials of which they were constructed. Those that are eaten by other animals undergo quite a different set of chemical changes in the animal's body, which may be said to result in the several constituents of the plant supplying nitrogenous substances to the animal's muscle, carbon to its fat, mineral matter to its bones. These, or some of these, are necessary to the life and health of every animal, and are what it cannot obtain from simple inorganic substances (except perhaps the mineral matters) unless these have been first taken up by plants and united together into more complicated compounds.

VI.—THE GROWING SEED.

GERMINATION.

32. It is well to commence the actual study of plants by that of the growth of the seed, as it is very easily observed, and a right understanding of the early history of the plant as studied in its seedling state is a great help to the learning of its later history.

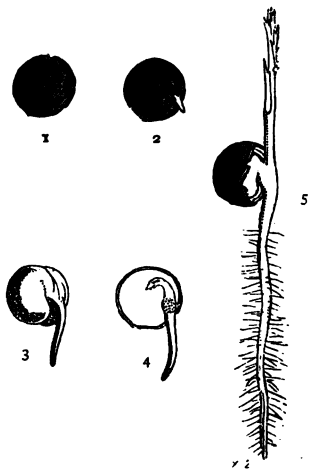

FIG. 10.—Germination of sweet-pea: 1 seed, 2 radicle pushing through the integument, 3, embryo with radicle elongated, 4 the same with one cotyledon removed, 5 the same further advanced; all twice the real size.

33. Take seeds of pea, mustard, and wheat, and place them on dry earth. So long as earth and seeds remain dry the seeds will not grow. Moisten them and put them where the temperature does not rise

above freezing; still they will not grow. Place them in a vessel from which all air is excluded; still they will not grow. Lastly place them where the temperature is considerably above freezing, and where air has access to them, and keep them moist, and they will grow whether in light or shade. This growth of a seed is called its **germination.**

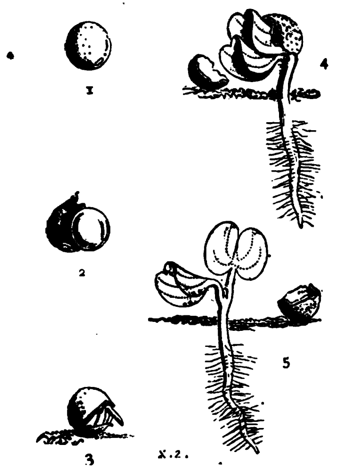

FIG. 11.—Germination of mustard: 1 seed, 2 embryo removed from integument, 3 radicle pushing through integument, 4 cotyledons and radicle after throwing off integument, 5 young plant; all twice the real size.

34. From these experiments we learn that to produce germination in a live seed, water, air, and a heat considerably above the freezing point are all required. And what is thus proved of the seed applies to plants throughout their lives—namely, that to grow they must have warmth, air, and moisture. Further on it will be shown that to grow to maturity light is also

wanted; but at present we are concerned only with the germinating seed.

35. From experiment now proceed to observation. All seeds consist of two principal parts—a dead part outside and a living part within it. The living part is the **plantlet,** or **embryo,** and is in fact an im-

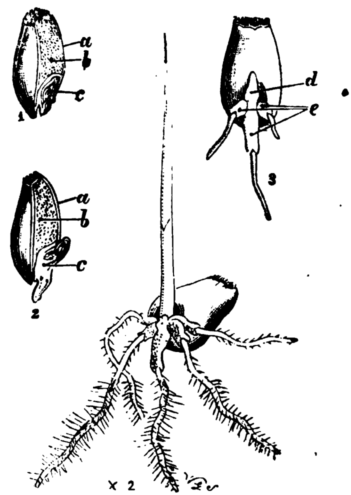

FIG. 12.—Germination of wheat: 1 seed cut vertically, showing—*a* the integument, *b* the albumen, *c* the embryo; 2 the same further advanced; 3 back view of grain, with *d* plumule, and *e* sheathed rootlets; 4 the same further advanced; all twice the real size.

mature plant, having a separate existence from that of its parent: the dead parts are its coverings (**integuments**), together with sometimes a nourishing tissue (**albumen,** Par. 135) provided for the plantlet, and like it contained within the integuments. The pea and mustard have no albumen; the wheat has.

36. The **plantlet** consists of different parts, which serve different purposes. In the pea (Fig. 10) it consists of two thick masses (**cotyledons**) placed face to face and united at one point of their margins. A small cylindrical body lies between the cotyledons where these unite, and is attached to them about its middle. It is conical at one end, and blunter at the other. When the seed grows, the conical end (the **radicle**), below the cotyledons, grows downwards and gives origin to the root of the plant. The blunter end (the **plumule**), which lies between the cotyledons, grows upwards and is the bud of the stem of the plant. To ascertain which is the radicle and which the plumule of the plantlet, the seed must sometimes be examined soon after it has germinated, when they are easily distinguished, whether by their form or by the directions they take.

37. This elongation of plumule and radicle is the first growth made by both the pea and the mustard, but after this they follow quite different modes of development.

In the case of the pea the cotyledons do not grow at all, but supply nourishment to the growing radicle and plumule, which absorb it through the points of attachment: after this, their nourishing matter being exhausted, the cotyledons shrivel and dry up, or rot. The plantlet thus feeds on the same substances as are eaten at table, and in so doing it empties the cells of the cotyledons of the starch, oils, albuminoids (Pars. 17 to 20) which they contained. Here, then, the cotyledons nourish the plumule and radicle from the very first.

In the case of the mustard, on the other hand,

whilst the radicle plunges into the soil, the cotyledons are carried up above ground, where they spread out to the light, become green, and assimilate food for the plantlet, as leaves do for full-grown plants.

38. In the wheat (Fig. 12), the plantlet lies on one side of the seed, between its integument and the albumen, which is white and floury. It has not two opposite cotyledons, but one, which forms a sheath around the leaves of the plumule. When germination begins, the plumule and radicle, not being in organic connection with the albumen, absorb nourishment from it by contact, and not as the pea and mustard, which draw theirs from the cotyledons. The plantlet here feeds on the flour of which we make bread, just as the pea plantlet fed on the part of the pea which we eat.

The radicle of the wheat does not elongate upon germination, as that of the pea and mustard did, but rootlets grow out from it with sheaths at their base.

39. These great differences between the cotyledons, the growth of the root, and the mode of germination of the pea (or mustard) and of the wheat, are characteristic of the two great divisions (classes) of flowering plants called **dicotyledons** (plants with two cotyledons or seed-leaves) and **monocotyledons** (plants with one cotyledon or seed-leaf), which divisions are further to be recognized by other characters hereafter to be described.

VII.—THE ROOT.

40. Roots are formed at the radicular extremity of the embryo (Pars. 34—36). Its uses to the plant are, to fix it to the ground, to absorb nourishment from

the latter, and sometimes to store up and retain nourishment during winter for the food of the plant during its growth in the following spring.

41. Roots are known from stems by their growing downwards from the plantlet (Pars. 34—36), and usually afterwards avoiding the light; by their not, or rarely, bearing buds; and by their structure and mode of growth.

FIG. 13.—Vertical section of tip of root-fibre of hyacinth, many times the real size.

42. When only a single prolongation of the radicle is formed this is called a **tap-root.** This bears at its side numerous slender branches or **root-fibres.** Sometimes the **tap-root** is very insignificant, and not easily distinguished from its fibre-like branches; the whole root is then distinguished as fibrous. **Root-fibres** are usually so slender that it is not easy to examine their nature; but this can be done in hyacinth roots, the tip of one of which, if cut down the middle, shows under a microscope that a sheath of soft flattened cells envelops the tip, within which is a mass of denser cells which form the growing point.

43. Root-fibres do not push themselves into the soil as one thrusts a stick into it; but they find their way through interstices in the soil as they elongate at the point. As the root-fibre elongates, the front part of the sheath decays, and the back part, which is constantly renewed by the growing point, takes its place, thus advancing and displacing water in the case of the hyacinth grown in a glass, and earth in other cases.

FIG. 14.—Root-hairs, many times the real size.

In shrubs and trees the root-fibres as well as the tap-root thicken as they grow, become woody, and displace the earth laterally as well as in front; and with such force does growth go on that stones of walls are frequently displaced by roots. In tropical countries the destruction of buildings is often caused by the power of growing roots; and neither conquering nations, nor earthquakes, nor fires, nor tempests, nor rain, nor all put together, have destroyed so many works of man as have the roots of plants,

which have all insidiously begun their work as slender fibres.

44. Nourishment is taken in by the **root-hairs** (Fig. 14), but not by the growing-point. Root-hairs are delicate outward prolongations of the cells forming the epidermis (Par. 6) of the radicle and of the root-fibres, and may be seen on the first formed root of the pea and mustard plants in great quantities (Figs. 10, 11).

45. Roots may be roughly classed under two heads —those that simply nourish the plant as it grows, and those that lay up a store of nourishment to assist the growth of the plant during the second year.

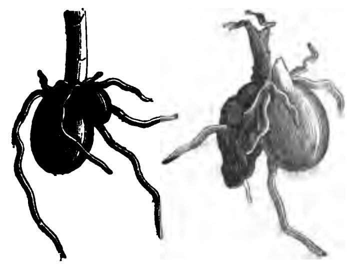

FIG. 15.—Tubercles and root-fibres of orchis.

To the first class belong (*a*) the very simple annual roots that consist wholly of simple fibres (hyacinth); (*b*) annual roots of much-branched fibres (grasses, groundsel); (*c*) branched roots whose fibres become woody in the second year (trees, shrubs, and herbs with woody roots).

To the second class belong (*a*) such roots as are fleshy and globose or spindle-shaped (turnip, carrot, radish, beet). These produce leaves the first year,

and in the second, leaves, flowers, and fruit, after which the whole plant dies. They are furnished with slender fibres from their sides and tip. (*b*) Roots with many fleshy branches, called tubercles (ficaria, dahlia). (*c*) Roots with only two fleshy tubercles like the orchis, which deserve a separate description.

46. The root of an orchis consists (besides some slender fibres) of two distinct fleshy tubercles, one large, the other small. Both grow at the bottom of the stem, below the fibres which spread horizontally from just above them. When an orchis is in flower, the flower-stem proceeds from the top of the large tubercle, which bears the smaller tubercle attached close to its neck. Later in the year, when the orchis is seed-bearing, the large tubercle will be found withered, while the little tubercle has grown large and plump, and bears a bud at its top. Still later, the whole plant dies, except the smaller tubercle with its bud, which latter will grow up as the orchis stem of the next year. Such an orchis is thus capable of travelling, and makes a little journey annually; but some kinds make a much longer annual journey, for the new root-tubercle, instead of being attached to the base of the stem close to the old root-tubercle, is attached to the former by a root-fibre sometimes six inches long; and such orchises make comparatively rapid marches under the ground.

47. **Adventitious Roots.**—Roots may also be thrown out from the stems of plants. This is taken advantage of in multiplying plants by cuttings. Such roots are called adventitious, and are found constantly on many mature plants of both monocotyledons (underground stem of couch-grass, Fig. 16), and of

dicotyledons (wall-roots of ivy), and they form the supports of the branches of the banyan-tree of India.

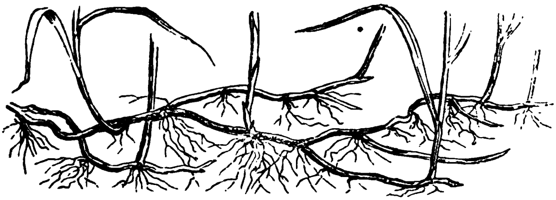

FIG. 16.—Creeping stems and roots of couch-grass.

VIII.—THE STEM.

48. The stem is formed by the elongation of the plumule of the embryo (Pars. 35, 36); its uses are to support the leaves, buds, and flowers, and to form a channel of communication by which the water absorbed by the roots is conveyed to them, and the starch formed in the leaves and other nutrient matters are distributed over the plant.

49. The stem usually seeks the light, but not always; for many stems grow underground, elongating, and even branching horizontally; such stems (mint, potato) are often mistaken for roots, from which they differ in their mode of growth, and in bearing leaves, buds, and flowers.

50. A stem may be simple (most palms) or branched. It is divided into **nodes** and **internodes**: the nodes are the points from which leaves arise; the internodes are the intervening portions of the stem or branch. The nodes are swollen in many plants (pinks, grasses);

in grasses the internodes are usually hollow while the nodes are solid.

51. Stems may be subterranean (primrose, couch-grass, Fig. 15) or ærial, and the latter are in most cases erect, prostrate, or twining.

The **twining** stem (hop, honeysuckle, convolvulus), of which some turn to the right, some to the left; but very rarely does one kind of plant turn either way indifferently. This twining habit is the effect of an inherent disposition in the tips of all elongating stems to bend successively towards all the points of the compass—a movement which is very obscure in plants with straight stems, but very marked in those that climb. The tip of such a stem, as it elongates, describes a wider and wider sweeping circle, till the stem strikes a support, when the portion above the point of contact with the support continuing to revolve as it lengthens, naturally twines round and ascends it. Such stems, if they find no support, become weak as they lengthen, and fall on the ground.

52. The principal underground forms of stem are—

(*a*) The **bulb,** a very short, usually underground bud (Par. 64), or undeveloped stem, with excessively crowded, overlapping leaves. These leaves sheath one another in the onion, but simply overlap in the tiger-lily.

(*b*) The **rhizome** or root-stock, an elongating underground stem, which sends root-fibres from its lower surface, and buds and leaves from its sides and tip (iris). The **corm** is a very short fleshy root-stock (colchicum). The **tuber** is a short fleshy subterranean branch (Par. 64).

(*c*) Small bulbs or corms are often formed at the

side of old ones, and are hence analogous to buds, under which they will be further noticed (Par. 64).

53. The tissues of the stem of flowering plants are arranged on two plans, one characteristic of dicotyledons, the other of monocotyledons (Par 39). These plans must be understood by the pupil, and can be so by a little patience and practice with specimens; they are best illustrated by three such examples as the mallow, lime, and butcher's broom, or asparagus.

54. The mallow plant (a dicotyledon) has an erect herbaceous stem of many internodes (Par. 50) with leaves all the way up, and flowers at the ends of the branches.

A magnified cross-cut of the stem shows that it consists of a cylinder of parenchyma (Par. 6), traversed vertically by a ring of wedge-shaped fibro-vascular bundles (Par. 9), which are separated from one another by the parenchyma. The central parenchyma is the pith, that at the circumference is the outer bark. The fibro-vascular bundles are in part inner bark and in part wood, and consist of wood-tissue (Par. 7) mixed with vascular-tissue (Par. 9) towards the centre, and of bast-tissue (Par. 8) towards the circumference. Of these components of the vascular bundle the bast-tissue forms the inner bark; the wood and vascular tissues form the wood of the plant. Such is the origin of outer bark, inner bark, wood, and pith.

A cross-cut of a one year's old twig of lime shows the same arrangement of tissues as the mallow; but whereas the mallow stem dies the same year as that in which it is formed, the lime twig lives through the winter, and is added to during the following summer increasing thus in thickness.

55. This increase of thickness is caused by new tissue being added between the bast and wood formed in the previous year. The new tissue con-

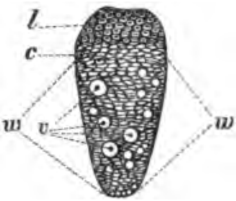

FIG. 17.—Transverse section of vascular bundle from stem of a dicotyledon; *l* bast; *c* cambium; *v* vessels; *w* wood-cells.

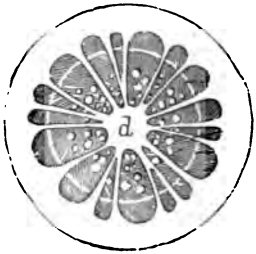

FIG. 18.—Transverse section of stem of a dicotyledon.

sists at first of soft thin-walled cells, produced in spring by the growth of the **cambium layer** (which lies between the bast and the wood) in the position indicated; and which gives rise to an additional layer of new bast-tissue inside the old bark, and new wood-tissue traversed by vessels outside the old wood.

56. Omitting details (such as the formation of layers of cork outside the bast-tissue), this is the plan upon which the stem and branches of plants with two cotyledons are formed. It has been called **exogenous,** because the bulk of the stem is increased by additions to the outside of the wood. Exogenous plants are hence synonymous with dicotyledons (Pars. 39, 53).

57. The branch or stem of a dicotyledonous tree or shrub (as the lime), if more than one year old, hence

consists, proceeding from the centre, of (1) pith; (2) layers of wood-cells intermixed with vessels, of which the oldest layers are next the pith; (3) layers of bast-tissue of which the oldest are next the circumference; (4) cortical parenchyma bounded externally by (5) layers of cork cells, of which the oldest are next the circumference; (6) rays of parenchyma (silver-grain) stretching from the pith to the circumference, and separating the wood into wedges.

58. The pith never grows in diameter after the first year; but the cortical parenchyma usually continues to grow, and the external older portions becoming indurated or partially converted into cork may finally be thrown off; of this the cork, plane, and birch trees afford conspicuous examples.

59. The stem or branch of the butcher's broom or asparagus (monocotyledons) has a totally different structure. A cross-cut (Fig. 19) shows that the whole

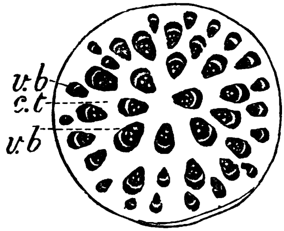

FIG. 19.—Transverse section of stem of a monocotyledon.

consists of a cylinder of cellular tissue (*c.t.*) traversed by isolated bundles (*v.b.*) of fibro-vascular tissue, (Par. 9), not arranged in a ring, or in concentric rings,

but scattered with little order through the cellular tissue, and much crowded at the circumference of the stem. Each of these isolated bundles consists outwardly of bast-cells and inwardly of wood-cells, exactly as in the first year's stem of flax or lime (Par. 54). These bundles do not, however, increase by the addition of bast-cells and wood-cells.

60. Commencing at the bases of the leaves, all the fibro-vascular bundles of a monocotyledon may be traced downwards, first arching inwards towards the centre of the stem, then gradually outwards to its circumference, where they are closely crowded. There is hence no fibrous bark, but the parenchyma surrounding the vascular bundles sometimes forms a distinct outer layer, as in the dragon-tree (*Dracæna*), in which tree also new bundles are formed which are disposed in concentric rings as in dicotyledons (Par. 56). The individual bundles are, however, not added to as in dicotyledons, and they are hence called definite bundles.

61. The arrangement of vascular bundles above described is characteristic of monocotyledons (Pars. 39, 53).

IX.—THE BUDS AND AXIL-BRANCHES.

62. Buds are formed in autumn, either at the ends of stems and branches, or at the angles where the leaves or leaf-stalks meet the stem, and remain dormant till spring. They have wood, pith, and bark continuous with those of the stem, with which their union is hence complete. They are usually protected from cold and wet by scales that are often covered with resin-secreting glands (Par. 138 *c*), or with hairs.

Some plants increase only by lateral buds (willow, horse-chestnut, elm); others by both terminal and lateral buds (ash and most trees).

63. Buds become leafy branches by the development of their internodes (Par. 50), and may produce leaves only, or flowers, or both; or they may in some rare cases fall away from the plant (tiger-lily), and form new plants, sending roots downwards and a stem upwards.

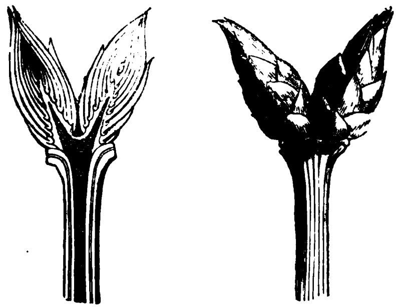

FIG. 20.—Leaf-buds and vertical section of ditto.

If the terminal bud produce only an inflorescence (Par. 75) its onward growth is stopped, and lateral buds form below it (Fig. 20) and are developed into branches. This takes place in the horse-chestnut and lilac. In many half-woody plants, the branches grow on indefinitely till killed by the winter's cold; new buds forming low down on the stem which develop similar branches in the following spring. The growth of many young shoots of most trees and of most branches of several is arrested in the same way.

64. Buds may, instead of simply elongating into branches, grow in width and form short fleshy **tubers**,

of which the potato is an example. A careful examination of a potato plant shows that it consists of an underground branched ascending stem, which bears root-fibres, and shortened fleshy tuberous branches (the potatoes), covered with eyes, which are buds in the axils of rudimentary leaves. The small bulbs (Par. 52), at the side of the bulb of a hyacinth or crocus are also buds which were formed in the axils of the scales (which are modified leaves).

65. The **tendrils** of the Virginia creeper are modified branches whose divisions expand at their tips into glue-tipped suckers, that fix the stems to the wall. The tendrils of the grape-vine are also branches which on finding a support twine round it, following the same course as twining stems (Par. 51). The **spines** of most plants are stiff shortened branches (hawthorn, sloe). (Prickles are quite different things, and will be explained in Par. 138 *e*.)

66. The branching of trees forms an admirable winter study, and one full of interest. It is sufficient to allude to the zigzag branchlets of the oak, with rounded terminal buds; the graceful, straight twigs of the beech, with lancet-shaped buds; the bold stout branchlets of the horse-chestnut, with ovoid buds; and the exquisite subdivided sprays of the elm, like lace-work against the sky. All these characteristic features are due to the form, direction, and setting on of twigs and buds, and are objects of equal interest to the botanist and the artist. Leafless branches of the common English trees suspended against a white wall are capital studies for pupils, and reveal characters that escape the observation of teachers whose attention has not been called to them.

X.—THE LEAVES.

67. Leaves (or foliar organs) are expansions of the parenchyma (Par. 6) continuous with that of the bark, traversed by fibro-vascular bundles (Par. 9). Their use is to afford a large surface for exposing to the action of sun-light and sun-heat the food-materials absorbed by the plant and thus cause assimilation (Par. 28); they also provide for transpiration (Par. 27); and they absorb the carbonic acid of the air (Pars. 26, 28).

68. The external characters of leaves are very various indeed, and are characteristic of whole groups as well as of individual kinds of plants. The following principal facts regarding the leaves of some common plants should be observed by the pupil:—

(*a*) As to duration. Whether they are **deciduous,** falling annually; or **persistent,** continuing a year or longer.

(*b*) As to position. Whether **opposite** (dead-nettle, maple, horse-chestnut); or **alternate** (lime, ivy, grasses); or whorled (woodruffe, bed-straw); or tufted (larch, cedar, pine).

(*c*) As to insertion. Whether by a stalk **(petiole)** (lime, &c.), or not **(sessile)**, or by a **sheath** (grasses); and whether the petiole is inserted at the bottom of the blade, as in most plants, or in the centre, as in the penny-wort.

(*d*) As to division. Whether **simple** (lime, ivy, oak), or **compound**—that is, formed of separate pieces **(leaflets)**, (ash, horse-chestnut, rose, pea, bean).

(*e*) Whether their margin is **entire** (privet); or **serrate,** with teeth pointing upwards (lime); or **toothed,** with teeth pointing outwards (holly); or

orifice. The stomates of most plants open more widely in the light than in the dark, and this must have the effect of promoting transpiration (Par. 27).

The glass-like sheen of the surface of leaves is due to the smoothness and transparency of the epidermis under which the cells full of chlorophyll granules are seen (Par. 16).

73. The **venation,** or arrangement of the fibro-vascular bundles in the leaf, is for the most part very different in dicotyledons and monocotyledons. In the former, one or more bundles enters the petiole (or the blade itself if sessile), and usually either runs to the end of the blade as a mid-rib, or sends a branch into each division of the leaf; while from each side of this mid-rib branches are given off that branch again, and by uniting form a network. In most monocotyledons either many bundles enter the leaf and run lengthwise through the blade (as iris), meeting at its tip, or one such bundle splits up at the base of the leaf into many that run as above; in most monocotyledons these main bundles are connected by straight transverse bundles. To these rules there are exceptions, but they are sufficiently constant to make it always worth while to examine the venation of a leaf together with the characters given in Pars. 39, 53, and 60, when referring a plant to one of these two classes.

74. The death and separation of the leaf previous to its fall from the parent plant are not accidental, but due to the following causes:—

First, and chiefly, because there is developed at the base of the leaf, or its stalk (if it has one), a transverse layer of cells which die after the leaf has performed its functions and thereby produce their

separation. The leaf consequently falls off, leaving a clean scar. Secondly, because the leaf rapidly acquires in spring its full size, whilst the branch on which it grows goes on thickening; consequently, the tissues at the point of union tend to become disunited. Thirdly, because the fluids taken in by the root go to the leaves; these fluids contain earthy matter, much of which is deposited in the leaf tissues, choking them, preventing them from performing their functions, and hastening their death. This is proved by burning spring leaves, which yield little ash, while autumn leaves yield relatively more even than wood. It is however remarkable that the substances contained in falling leaves are those which have ceased to be of value to the plant. The starch and protoplasmic substances, together with the most important mineral matters such as phosphoric acid and potash, are transferred to the permanent parts of the plant before the leaves fall.

XI.—INFLORESCENCE.

75. This term denotes the arrangement of the flowers on the stem or branch of a plant, which follows several very distinct plans.

76. The simplest inflorescence is that of a one-flowered plant, like the tulip, whose flower-stalk (**peduncle**) is terminal; the next is such as the pimpernel or dog-violet, whose single flowers spring from the axils of leaves. When the peduncle is many-flowered, the form of inflorescence depends on the arrangement of the partial flower-stalks (**pedicels**) upon the peduncle, and the order in which they open.

on the same plan as are the leaves, but taking different shapes and performing different functions according to the requirements of the plant.

82. Before describing the individual floral whorls, it will greatly facilitate the student's progress to familiarize him with their number, form, and relative positions in flowers which differ very widely from one another. Beginning from without, the floral whorls in the plants enumerated in this paragraph are :—

(*a*) **Calyx**; it forms the outer, or protective, whorl, is usually green, and its pieces, called **sepals**, may be separate (distinct), or combined into a cup or tube, wholly or in part only.

(*b*) **Corolla**; it forms the second, or attractive, whorl; it is white or coloured (very rarely green), in order to attract insects to the flower; a sugary fluid (**nectar**) is often exuded at particular points upon it. Its pieces, called **petals**, may be distinct or combined into a cup or tube, or into the form of a bell, a funnel, &c.

(*c*) **Stamens**, usually slender organs form the third whorl; they consist of a stalk (**filament**), surmounted by a 2-lobed body, the **anther**, containing a fine, usually yellow, powder (**pollen**), necessary to perfecting seeds. The filaments may be absent; or combined into a tube, or into bundles, or may be altogether separate, as may the anthers.

(*d*) The **Pistil** forms the innermost or fourth whorl, and presents many more modifications than any of the preceding. In its simplest form (pea) it represents a leaf folded down the middle with its edges united so as to form a hollow vessel (**ovary**); the tip tapers into a stout or slender body (**style**), which terminates in one or more rough or moist, often swollen knobs or

surfaces or points (**stigmas**). The style may be absent, when the stigma is sessile on the ovary.

Such a pistillar leaf is called a **carpel**, and its cavity contains, usually attached at the angle formed by its united edges, one or more minute bodies (**ovules**), destined, after fertilization (by the action of the pollen), to become seeds. The pea-pod is one such carpel with several ovules. The buttercup has many such carpels, each with one ovule, style, and stigma. When there are several carpels they may be distinct (buttercup), or combined by their edges into an ovary with a single cavity (**cell**) (violet), or by their sides into an ovary with as many cells as carpels (lime). In these cases of united carpels the styles may be distinct or combined; and when combined, the stigmas may still be distinct. The number of carpels of which a pistil is formed, when these are combined, may often be ascertained from the number of cells of the ovary, or of styles, or of stigmas.

(*e*) The floral **receptacle** is the tip of the flower-stalk which bears the floral organs. The **disk** is a thickening of the receptacle between the pistil and corolla or calyx; it is often swollen (rue, lime), and secretes nectar; or it is represented by scales or small prominences. The stamens may be inserted around it, or on it, or between it and the ovary.

83. If a flower contains all four floral whorls (Par. 81), it is called **complete**; if fewer, **incomplete.** The calyx and corolla together form the **perianth**; also when the calyx is undistinguishable from the corolla, or when either of these is absent, the outer floral whorl takes the name of perianth.

Of the floral whorls, the calyx is seldom absent,

corolla less seldom. The stamens and pistil cannot both be absent, but either may be: in this case the missing whorl will be found in correspondingly incomplete flowers, borne on the same or some other individual plant. Very few flowers have fewer than two sepals or two petals, but many have either no stamens or no pistil; and a flower may consist of a stamen only, or a pistil only.

An **irregular** flower is one in which one or more of the parts of the calyx or corolla are of different shape (pea, snapdragon). A **regular** flower is one in which this is not the case, but the members of each whorl are equal and similar (strawberry, buttercup).

A **symmetrical** flower is one whose sepals, petals, and stamens are equal in number or multiples of one another.

84. The principal modifications of the flower depend on (*a*) the absence of one or more of the above whorls and the form of those that exist; (*b*) on the members of each being separate or combined; (*c*) on the members of one whorl being free or adherent to those of the one next outside or inside of it; (*d*) on the position of each whorl upon the receptacle. Of these modifications, the most obvious is that the ovary is sometimes superior, that is placed above the calyx (buttercup, Fig. 22), while sometimes the ovary is inferior, or apparently below it (snowdrop, daffodil, Fig. 37). In the latter case, the appearance is caused either by the ovary being sunk in the top of the flower-stalk, and becoming united with it, or by the lower part of the calyx adhering to the walls of the ovary; in either case the corolla, disk, and stamens are carried up above the level of the ovary, and are, as it were,

inserted above or upon it. The rose (Fig. 31) and apple (Fig. 32) are obvious examples of the ovary being sunk in the swollen top of the flower-stalk.

85. The flowers enumerated below are now to be examined, and the pupil taught to name the organs of each and their uses; this done, the organs should be described according to their modifications. In doing so, attention should first of all be given to the following points :—

(*a*) Whether the flower is complete (Par. 83); if not, which whorls are absent.

(*b*) The number of members of each whorl, and whether they are opposite or alternate with the members of the whorls outside it.

(*c*) Whether the members of each whorl are separate, or combined together; and whether they are free, or adhere to those of the whorl outside or inside of them.

(*d*) Whether the flower is regular or irregular (Par 83).

(*e*) Whether the flowers are **bisexual**, having both stamens and pistil (buttercup), or **unisexual**, having one only of these; and if the latter, whether the flowers that bear the stamens are **monœcious**, that is, on the same individual with those that bear the pistil (oak, nut), or **diœcious**, that is, on another individual (willow, common nettle).

(*f*) Whether the perianth (Par. 83) is inferior, or superior (Par. 84).

A.—Flowers with a double inferior perianth.

Buttercup (Fig. 22).—Flower regular. Calyx of 5 separate sepals. Corolla of 5 separate petals alternate

with the sepals. Stamens many, seated on the receptacle. Pistil of many separate carpels.

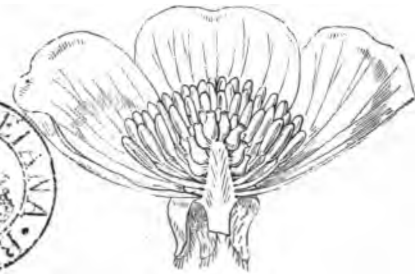

FIG. 22.—Vertical section of buttercup flower, enlarged.

Bramble (Fig. 23).—Flower regular. Calyx of 5 sepals combined at the base. Corolla of 5 petals, alternate with the sepals. Stamens many, seated on the calyx. Pistil of many separate carpels. (Note the different insertion of petals and stamens of buttercup and bramble.)

FIG. 23.—Vertical section of bramble-flower, enlarged.

Wallflower (Figs. 24, 25).—Flower rather irregular. Calyx of four separate sepals, two inserted lower down

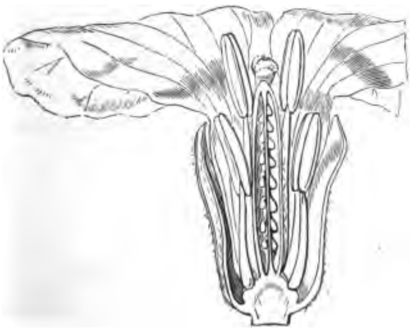

FIG. 24.—Vertical section of wallflower, enlarged.

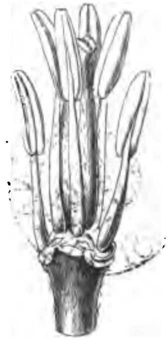

FIG. 25.—Stamens and pistil of wallflower, enlarged.

than the others. Corolla of 4 separate petals, alternate with the sepals. Stamens 6, two shorter than the others. Pistil of 2 combined carpels, forming a 2-celled ovary with a very short style and notched stigma.

Pink.—Flower regular, with many bracts. Calyx of 5 sepals combined into a 5-cleft tube. Corolla of 5 separate petals alternate with the sepals. Stamens 10, five alternate with and five opposite to the petals. Pistil of 2 combined carpels forming a 1-celled ovary with 2 styles.

Mallow (Fig. 26).—Flower regular, with 3 bracts. Calyx of 5 combined sepals. Corolla of 5 separate petals, alternate with the sepals, and singly inserted on the bundle of united filaments. Stamens very many, filaments combined into a tube which adheres

at the base to the petals. Pistil of many combined carpels, with many combined styles with separate stigmas.

FIG. 26.—Vertical section of mallow-flower, enlarged.

Pea (Fig. 27).—Flower irregular. Calyx of 5 com-

FIG. 27.—Vertical section of pea-flower, enlarged.

bined sepals. Corolla of 5 very unequal petals of which the two innermost are often combined. Stamens 10, 9 combined and 1 separate. Pistil of 1 carpel, with 1 style and stigma.

Primrose (Figs. 28, 29).—Flower regular. Calyx of 5 combined sepals. Corolla of 5 petals combined into a tube below. Stamens 5, opposite the petals, their filaments combined with these. Pistil with a 1-celled ovary having 1 style and stigma.

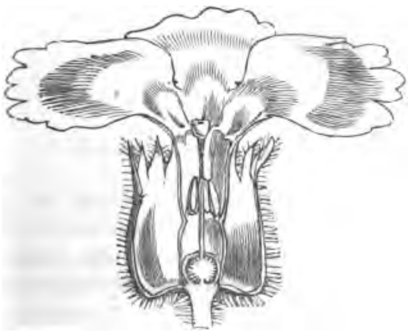

FIG. 28.—Vertical section of china-primrose-flower, enlarged.

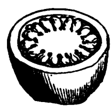

FIG. 29.—Transverse section of ovary, enlarged.

Dead-nettle (Fig. 30).—Flower irregular. Sepals 5, combined into a cup. Corolla of 5 petals combined into a tube with two lips; lobes alternate with the sepals. Stamens 4, 2 longer than the others

Pistil of two carpels forming a 4-celled ovary with 1 style and cleft stigma.

FIG. 30.—Vertical section of dead-nettle-flower, enlarged.

Rose (Fig. 31).—Flower regular. Calyx of 5 sepals. Corolla of 5 separate petals alternate with the sepals. Stamens many, seated on the calyx. Pistil of many separate carpels seated on the hollowed top of the peduncle.

FIG. 31.—Vertical section of rose-flower, enlarged.

B.—Flowers with a double superior perianth.

Apple (Fig. 32).—Flower regular. Calyx of 5 sepals. Corolla of 5 separate petals alternate with the sepals. Stamens many, seated on the calyx. Pistil of 5 slightly-combined carpels, with 5 separate styles.

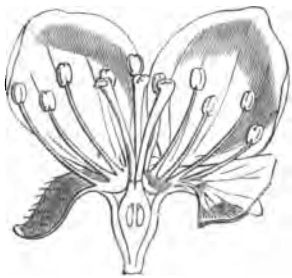

FIG. 32.—Vertical section of apple-flower, enlarged.

Gooseberry.—Flower regular. Calyx of 5 sepals. Corolla of 5 separate petals alternate with the sepals. Stamens 5, alternate with the petals, seated on the calyx. Pistil of 2 carpels combined, forming a 1-celled ovary with 2 styles.

Campanula.—Flower regular. Calyx of 5 sepals. Corolla of 5 combined petals alternate with the sepals. Stamens 5, alternate with the petals, seated on the top of the ovary. Pistil of 3 or 5 carpels combined into a 3- or 5-celled ovary, with 1 style and 3 or 5 stigmas.

Elder.—Flower regular. Calyx of 5 sepals. Corolla of 5 combined petals alternate with the sepals. Stamens 5, seated on the corolla and alternate with

its petals. Pistil of 2 combined carpels with 2 cells and a short style and stigma.

Honeysuckle.—Flower irregular. Calyx with 5 minute teeth. Corolla of 5 petals combined in a tube. Stamens 5, seated on the corolla, alternate with its petals. Pistil of 3 combined carpels with 3 cells and 1 style and stigma.

Daisy (Figs. 33, 34).—Flowers of two forms in a compact head surrounded by green bracts. *Outer*

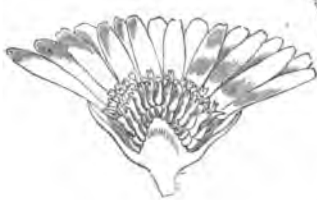

FIG 33.—Vertical section of head of daisy, enlarged.

FIG. 34.—Inner flower laid open from head of daisy, enlarged.

flowers unisexual, monœcious (Par. 85 *e*), irregular. Corolla white, of 5 petals combined into a narrow long ray. Stamens 0. Pistil with 1 cell, 1 style and 2 stigmas. *Inner flowers* bisexual, regular, of 4 or 5 petals combined into a yellow tubular 4-5-cleft corolla. Stamens 4 to 5, seated on the corolla, alternate with its petals, anthers combined. Pistil as in the outer flowers.

C.—Flowers with a single inferior perianth.

Dock.—Flower regular. Perianth of 6 nearly separate pieces. Stamens 6, seated at the base of the perianth, in pairs alternating with the three inner perianth pieces. Pistil of three combined carpels, with 1 cell and 3 styles.

Daphne (Fig. 35).—Flower regular. Perianth of 4 combined pieces. Stamens 8, seated on the perianth, 4 upper opposite, 4 lower alternate with the perianth pieces. Pistil of one 1-celled carpel with 1 style and stigma.

FIG. 35.—Vertical section of daphne-flower, enlarged.

Tulip (Fig. 36).—Flower regular. Perianth of 6 separate pieces. Stamens 6, opposite the pieces of the perianth. Pistil of 3 carpels combined into a 3-celled ovary with 1 style and a 3-lobed stigma.

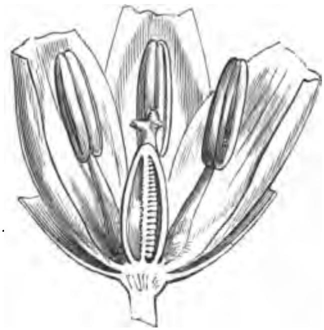

FIG. 36.—Vertical section of tulip-flower.

D.—Flowers with a single superior perianth.

Daffodil (Fig. 37).—Flower regular. Perianth of 6 pieces with a raised crown. Stamens 6, seated on

FIG. 37.—Vertical section of daffodil-flower.

the tube of the perianth opposite its pieces. Pistil of 3 combined carpels with 3 cells and 1 style and stigma.

Orchis (Fig. 43).—Flower irregular. Perianth irregular, of 6 pieces. Stamen 1, combined with the style. Pistil of 3 carpels combined into a 1-celled ovary.

E.—Flowers without an obvious perianth.

Willow (Figs. 38, 39).—Flowers unisexual, diœcious (Par. 85 *e*), in catkins (78). Catkins of two kinds, on different plants, both formed of overlapping scales; those of one kind of catkin each overlying one or more stamens; those of the other catkin overlying each a pistil. Pistil of 2 carpels combined into a 1-celled ovary with 1 style and 2 stigmas.

FIG. 38.—Male flower of willow, enlarged.

FIG. 39.—Female flower of willow, enlarged.

Wheat (Fig. 40).—Flowers consisting of 2 minute scales (the perianth), 3 stamens, and 1 pistil, the whole

inclosed in two sets of green bracts. Pistil with 1 cell and 2 styles.

FIG. 40.—Spikelet of wheat, enlarged. *a*, *b*, bracts; *c*, perianth; *d*, stamens; *e*, pistil.

86. It has been already stated (Par. 81) that the above organs of a flower are all formed on the plan of leaves, but modified for different purposes. The best evidence of this is afforded by, (*a*) the green hellebore, which shows the transition from leaves to bracts; (*b*) the calycanthus, from bracts to sepals, and from sepals to petals; by (*c*) the white water-lily, which shows the transition from sepals to petals, and from petals to stamens; (*d*) the garden rose, and most double flowers, which show the transition from petals to stamens; (*e*) the double tulip, which shows the transition from stamens to pistil; (*f*) the double cherry, in which the carpels appear as green leaves.

87. The number of sepals, petals, and stamens is in dicotyledonous plants, most frequently 4 to 5 each, or a multiple of those numbers; whereas 3 or a multiple of that number prevails in monocotyledons. This is the fourth means of distinguishing plants of these classes (see Pars. 39, 53, 60, 73).

XIII.—THE CALYX.

SEPALS.

88. The calyx is formed of a whorl of separate or combined organs called **sepals.** They are usually green and leaf-like in texture and often persist in the fruit. Their use is to protect the parts of the flower within them.

89. Although the outermost of the floral whorls, the calyx sometimes appears to be placed at a higher level than the ovary. This is because either the pistil is sunk in the swollen top of the peduncle (rose, Fig. 31); or because the calyx adheres more or less to the sides of the ovary, its free parts spreading out above. Hence the employment of the terms calyx superior and calyx inferior, which are equivalent respectively to ovary inferior and ovary superior (Par. 84).

90. The sepals of the calyx may be separate from one another when the calyx is polysepalous (buttercup, Fig. 22); or combined, when it is gamosepalous, often inaccurately called monosepalous (primrose, Fig. 28.)

91. The most curious modification of calyx is that of the dandelion, groundsel, thistle, and many other plants with their flowers in heads (Par. 78 *c*). Here the ovary is inferior, and the superior portion of the calyx is represented by a tuft of fine hairs called a

pappus (thistle, Fig. 42). In the dandelion (Fig. 41), the superior portion of the calyx is drawn out into a fine stalk crowned by the pappus. The valerian has a similar calyx. In these plants the feathery calyx assists in the dispersion of the fruit. The calyx may take some of the irregular shapes to be described under the corolla.

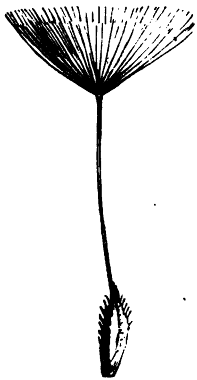

FIG. 41.—Dandelion fruit with pappus, enlarged.

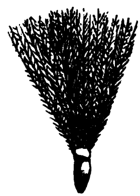

FIG. 42.—Thistle fruit with pappus.

XIV.—THE COROLLA.

PETALS.

92. The corolla is formed of a whorl of separate or combined organs called **petals.** It is usually coloured and thin, and much larger than the calyx; it is often scented and soon fades, rarely persisting in fruit (which it does in the ling). Its use is to attract insects and birds to flowers for the purpose of

fertilizing them (Par. 119), and it also often protects the parts of the flower within it. The many colours of flowers, their various shapes and scents, and their nectar, are so many baits for insects.

93. The corolla is inserted on the receptacle (Par. 82 *e*) in the buttercup; on the calyx, in flowers with a superior calyx, such as the apple (Fig. 32) and rose (Fig. 31). In campanula it is apparently inserted on the top of the ovary, but really on the calyx where this becomes free from the ovary.

94. The petals of the corolla may be separate from one another, when the corolla is polypetalous (buttercup, Fig. 22); or combined, when it is gamopetalous (primrose, Fig. 29).

FIG. 43.—Spotted-orchis-flower, enlarged.

95. The so-called irregularity or regularity of flowers (Par. 83) depends mainly upon the form of the corolla, and has reference to the visits of insects, &c. for the

purpose of fertilization. Of these irregular forms the most common gamopetalous one is the two-lipped or personate (snapdragon, deadnettle, Fig. 30); and the most common polypetalous one is the butterfly-shaped or papilionaceous (clover, pea, Fig. 27). The latter is so characteristic of a very large family of plants (pea family) that names have been given to its five petals; the upper being called the standard, the two side ones wings, and two within them, which are often combined by their lower margins, the keel. If the visits of bees to irregular flowers are watched, it will be seen, in very many cases, that the form of the corolla is singularly adapted to facilitate the insect entering it in order to obtain nectar for itself, when it also carries away pollen from the stamens (Par. 123).

96. The commonest regular gamopetalous corollas are the bell-shaped (campanula), funnel-shaped (convolvulus), salver-shaped (primrose), and wheel-shaped (pimpernel). In these, as in the regular polypetalous corollas (apple, Fig. 32, buttercup, Fig. 22), there is little or no relation between the form of the flowers and those of the insects that visit them. In some instances however of regular gamopetalous flowers, there is a special adaptation of the organs of the flower to those of the insect, as where the corolla has a long tube and the insect a long proboscis; the bee and primrose afford an example (Par. 122).

97. Petals are formed of a thin plate of cellular tissue traversed by vascular bundles (Par. 9). Their colouring follows certain rules. The corollas of few or no plants present all the primary colours, and white alone is found in all families of plants with coloured corollas. White and various shades of

yellow and red are found in roses, tulips, and rhododendrons, but never blue. Blue, yellow, and white are found in gentians, but very rarely red. Anemones are amongst the few plants in the different kinds of which red, yellow, blue, and white are found. Night-flowering plants have usually large, white, very strong-scented corollas, on purpose to attract moths. Certain lurid red or purple flowers both look and smell like putrid meat, and hence attract flies, which lay their eggs on them and fly away with the pollen.

98. Nectar when secreted on the corolla is usually at its very base (honeysuckle, crown-imperial), and to reach it the insect has to disturb or brush against the stamens, and hence carry away pollen. In the grass of Parnassus, the honey is secreted in the tips of the branches of an elegant comb-like scale opposite each petal. The glands that secrete the nectar are called **nectaries.**

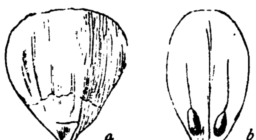

FIG. 44.—Nectaries of, *a*, buttercup; *b*, barberry; both enlarged.

XV.—THE DISK.

99. Usually at the base of the stamens and around that of the ovary, there is a thickened ring of cellular tissue, or a whorl of swellings, scales, or glands. It very often secretes a sugary fluid when the corolla does not, and is a part of the floral receptacle (Par. 82 *e*). I

the buttercup (Fig. 22) there is no disk; in the bramble (Fig. 23) it forms a thickened shining lining of the base of the calyx; in the orange (Fig. 45 *a*) and mignonette (Fig. 45 *b*) it forms a distinct cushion;

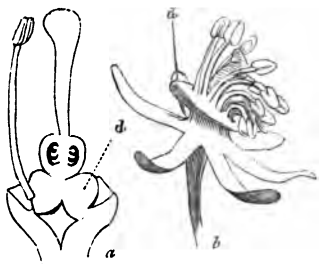

FIG. 45.—Disks (*d*) of, *a*, orange; *b*, mignonette; both enlarged.

in the wallflower (Fig. 25) it appears as two moist glands at the base of the short stamens; and in the carrot and similar flowers it crowns the ovary.

XVI.—ÆSTIVATION.

100.—As the folding together of the leaves in bud is called vernation (Par. 69), so that of the floral organs is called æstivation. In this folding that of the sepals never interferes with that of the petals, and these often follow quite different plans. These plans are usually constant throughout the flowers of any one kind of plant, and the same plan prevails through many allied plants; so that æstivation is a guide to the detection of relationships amongst plants.

101. There are four principal plans of æstivation. 1. **Imbricate,** when one or more pieces are outside

the others, which others may all overlap by one margin, or one of them may be inside all the others (petals of apple). 2. **Twisted,** when each overlaps by one margin the contiguous margin of that next to it (corolla of periwinkle, the divisions of which are simply twisted, and convolvulus, in which the whole corolla is plaited and twisted). 3. **Valvate,** when the sepals or petals meet by their edges without overlapping (calyx of mallow). 4. **Open,** when they grow quite apart, neither overlapping nor touching (petals of mignonette).

FIG. 46.—Æstivations: *a*, imbricate; *b*, twisted; *c*, valvate, with the edges turned outward.

102. The stamens usually grow straight from the first, but are sometimes curved or rolled inwards (myrtle and nettle), or backwards (kalmia).

XVII.—THE STAMEN.

ANTHER, POLLEN, FILAMENT.

103. The stamen consists essentially of the **anther,** a 2-lobed organ filled with granules (the **pollen**); its lobes are placed right and left to the axis of the flower. The anther may or may not have a stalk (**filament**), which contains a vascular bundle (Par. 9) that terminates between the anther-lobes. The use of the stamen is to form, contain, and discharge the pollen.

104. Stamens are variously inserted, but always within the calyx and corolla and outside the pistil, if these be present. They vary in number, and may be in one or more series; when equal in number to the petals or divisions of the perianth, they usually alternate with these in dicotyledons; but are apparently opposite to them in monocotyledons (because both the stamens and pieces of the perianth each form two alternating whorls); when twice as many they are alternate and opposite. They are inserted on the receptacle in the buttercup (Fig. 22), on the calyx in the bramble (Fig. 23), on the disk in the lime and mignonette (Fig. 45), on the corolla in the primrose

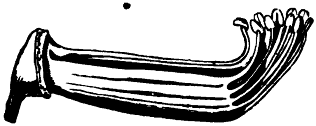

FIG. 47.—Stamens of pea, nine combined and one separate; enlarged.

(Fig. 29), and the single stamen is combined with the pistil in the orchis (Fig. 43). The filaments are separate in most plants; more or less combined in the mallow (Fig. 26); combined by bundles in St. John's wort; nine are united together and one is separate in the pea (Fig. 47). The anthers are usually separate, but are combined in the thistle and daisy, in which the filaments are separate.

105. The anther in its early state is a cellular 2-lobed body, with longitudinal rows of special cells in the centre of each lobe. The contents of each of these special cells (called mother-cells) divide into four, which form as many pollen grains. These pollen grains are also cells, and are provided with a cellulose

wall, ultimately divided into two layers or coats. They escape from the mother-cell and usually lie loose in the cavity of the anther.

106. When fully formed the anther-cells open to allow the pollen to escape, in most plants by longitudinal slits on the face (towards the pistil); but in some by lateral slits (buttercup), or dorsal ones (iris). In the heath order the anthers open by terminal pores (Fig. 48 *b*), which in the bilberry (Fig. 48 *a*) are at the end of long tubes. In the barberry (Fig. 48 *c*)

Bilberry. Heath. Barberry. Mistletoe.

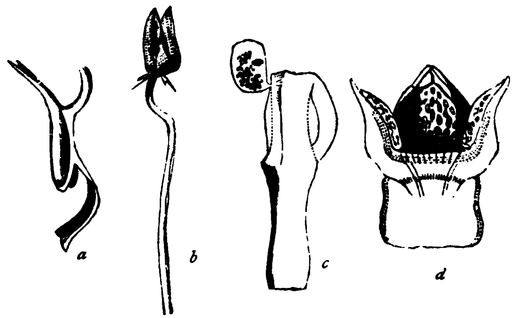

FIG 48.—Stamens of, *a*, bilberry; *b*, heath; *c*, barberry; *d*, mistletoe; all much enlarged.

they open by oblong lids that in some cases fall away; and in the mistletoe (where the anthers are adnate to the perianth segments) (Fig. 48 *d*) by many holes, each of which is full of pollen.

107. The relation of the stamen to the leaf is not so often clearly seen as are those of the sepals, petals, and carpels; nevertheless the transition from petal to stamen is obvious in the white water-lily, and in many double flowers, as the rose (Fig 49).

108. The **pollen** grains are usually globose, or ellipsoid, or rounded with obtuse angles; they are

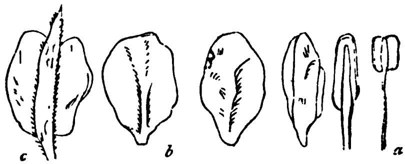

FIG. 49.—Transition from stamen *a*, to petal *b*, and to sepal *c*, in double rose

generally free, but sometimes escape from the mother-cell connected in fours (rhododendron). In orchis they are glued together into club-shaped masses (Fig. 57). The surface of the granules is smooth, sculptured, or prickly, and this and their size and shape are very constant in each kind of plant, and prevail through many allied plants.

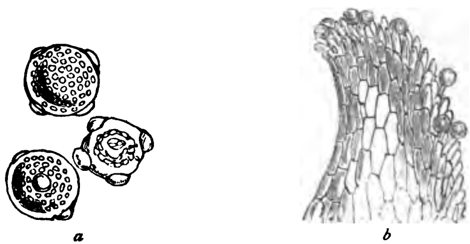

FIG. 50.—*a*, pollen grains of orange; *b*, pollen grains of buttercup upon the stigma with their tubes descending; both very much enlarged.

A pollen grain is a cell with fluid protoplasmic contents. The cellulose wall has two distinct layers or coats. When placed on the stigma (Par. 112),

one or more tubes formed of the inner coat are pushed through slits or holes in the outer, and descend through the stigma and style to the cavity of the ovary, finally conveying protoplasmic fluid from the pollen to the ovule.

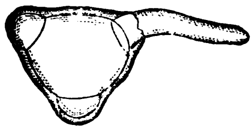

FIG. 51.—Pollen-grain of evening-primrose emitting a pollen tube; very greatly enlarged.

XVIII.—THE PISTIL.

OVARY, STYLE, STIGMA.

109. The pistil is by far the most complicated organ of the flower, and consists of one or more carpellary leaves (Par. 82 *d*). If it is composed of many such leaves, these may be so combined as to form a one- or many-celled ovary. Its use is to produce within its cavity **ovules**, destined to become seeds, and to provide means for conducting the contents of the pollen to the ovules.

110. The **ovules** are generally produced on the edges of the carpellary leaf; which presents a spongy thickening called the **placenta**, upon which the ovules are sessile, or attached by a short or long cord or stalk called the **funicle.**

The position of the placenta depends on the composition of the pistil; if the latter is formed

of one carpel (pea, Fig. 27) the placenta will be along the angle formed by the united edges of the carpellary leaf; if two or more carpels are united by their edges only into a one-celled ovary (Fig. 53), the ovules will be **parietal**, *i.e.* on the walls of the cavity of the ovary: or on a free central placenta, *i.e.* on a prolongation of the receptacle into the cavity of the ovary (Fig. 28); but if two or more carpels are combined by their sides into one, so as to form a two- or more-celled ovary, the ovules will be **axile**, *i.e.* situated on the axis of the ovary (Figs. 36, 37, 52).

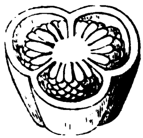

FIG. 52.—Axile ovules.

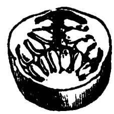

FIG. 53.—Parietal ovules.

111. The **style** consists of a column of cellular tissue continuous with the midrib and margins of the carpellary leaf or leaves, enclosing a core of looser cellular tissue amongst which the pollen tubes (Par. 108) descend to the ovary.

112. The **stigma** occupies the top, or the sides of the top of the style; or of the ovary if there is no style. It is not covered with epidermis (Par. 6), which would obstruct the entrance of the pollen tubes, and is frequently formed either of short loose cells, which exude a viscid fluid that holds the pollen grains and hastens the protrusion of their tubes, or of long cells forming tufts of hair amongst which the pollen grains become entangled.

XIX.—THE OVULE.

113. The **ovule** is a minute body enclosed in the ovary, and destined, after being fertilized (Par. 116) by the pollen, to become a seed, and to contain an embryo or plantlet. There may be one, few, or many ovules in an ovary; and if there are two or more, all, or a few, or one only, of these may be fertilized and become seeds.

114. In its earliest stage the ovule consists of a **nucleus,** which is a most minute swelling of cellular tissue formed on the placenta (Par. 110). Next a ring of cellular tissue grows up around the base of the nucleus and all but envelops it, leaving a canal or hole (**micropyle**). Often a second ring forms at the base of the first, and is similarly developed into an outer covering. A vascular bundle (Par. 9) runs from the edge of the carpellary leaf through the placenta into

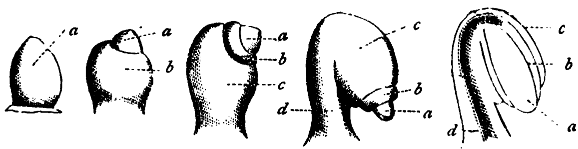

FIG. 54.—Growth of ovule of celandine; *a*, nucleus; *b*, first formed covering; *c*, second covering; *d*, funicle—very greatly enlarged.

the ovule, reaching the base of the nucleus, and is concerned in its nutrition and in that of the seed.

115. The ovule may be straight, or it may grow obliquely, or it may as it were turn round on itself by the greater growth of one side, so as to become completely inverted, when the micropyle, instead of being distant from the placenta, is brought into

proximity to it, and the base of the nucleus is at the top of the ovule. In this last case the vascular bundles from the placenta run up the side of the ovule to the base of the nucleus.

XX.—FERTILIZATION.

116. This essentially consists in the mixing of the contents of a pollen-grain with those of a cavity formed within the nucleus (Par. 114) of the ovule. Before this can take place, a single cell towards the upper end of the nucleus has become much enlarged and eventually formed this cavity which is lined with a delicate membrane (the **embryo sac**) and contains

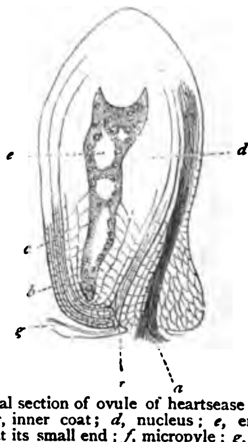

FIG. 55.—Longitudinal section of ovule of heartsease: *a*, vascular bundle; *b*, outer coat; *c*, inner coat; *d*, nucleus; *e*, embryo sac, with the germinal vesicle at its small end; *f*, micropyle; *g*, end of pollen tube—very much enlarged.

protoplasm. The pollen tube (Par. 108), after entering the cavity of the ovary, finds its way along the canal of the micropyle (Par. 114), comes in contact with

the nucleus and penetrates its cellular substance till it reaches the embryo sac (Fig. 55). Within this sac near its top a dark spot is seen (**germinal vesicle**), which, after the application of the tip of the pollen tube to the embryo sac, acquires a cellulose coat, and becomes a new cell. This, by division (Par. 13), gives origin to a filament, from the end of which the embryo is developed. Other portions of the protoplasm of the embryo sac give origin to the cells which form the **albumen** (Par. 135).

117. Though stamens and pistil frequently occur in the same flower, it does not follow that the pistil of such a flower is fertilized by its own stamens. On the contrary, it has been proved by many careful observations and experiments that nature has provided that pistils should be fertilized by pollen from other flowers, or from the flowers of other plants of the same species. Hence some plants bear stamens and pistils on separate flowers of the same individual (oak, hazel); others have stamens and pistils on different individuals (willow); in others again, where stamens and pistil do occur in the same flower, they do not become mature at the same time; and in still others, where stamens and pistil do occur in the same flower and are mature at the same time, they are so placed in reference to one another or to the corolla, &c., that the pollen cannot reach the pistil.

118. It has also been proved, that, as a rule, a pistil fertilized by the pollen of another flower, or that of the flower of another individual of its own kind, produces more and larger seeds which grow into stronger plants, than if it had been fertilized by the pollen of its own flower.

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119. These and many other observations tend to prove that the elaborate structures, colours, scents, sugary secretions, and other attractions of the corolla, stamens, and pistil, and their adjustments to one another and to the forms and habits of insects, are all intended to prevent flowers from being fertilized by their own pollen, and to facilitate their being fertilized by pollen brought from other flowers. This operation is called cross-fertilization.

120. In respect of fertilization flowering plants may be roughly classed under two heads, according as the pollen is carried to the pistil by the wind or by insects.

Wind-fertilized plants have, as a rule, stamens and pistil in different flowers or individuals. Their flowers are not bright-coloured, are scentless, and have no sugary secretions, and their stigmas are covered with hairs that retain the pollen; in some the anthers hang

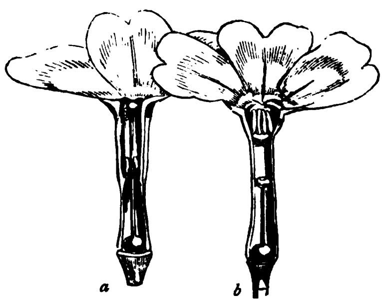

FIG. 56.—Vertical sections of corolla of, *a*, long-styled, and *b*, short-styled primrose.

out of the flower (poplar, willow, oak); their pollen is abundant, dry, and powdery (birch, alder, pine).

121. Insect-fertilized plants, on the other hand, present innumerable contrivances to ensure the fertilization of the pistil by pollen from another flower or plant, of which the following examples must suffice.

122. The primrose has two sorts of flowers, which never occur on the same plant; one has the stamens far down the corolla tube, and a long style with the stigma above the anthers, the other has stamens high up the tube and a short style with the stigma below the anthers; both have nectar at the very bottom of the corolla tube. When a bee visits a short-styled flower, it thrusts its proboscis to the bottom and, withdrawing it, brings away some pollen at its base. If it then visits another short-styled flower it cannot fertilize it, and only takes more pollen away; but if it visits a long-styled flower it must deposit pollen on its stigma, that being at the mouth of the corolla. If, on the other hand, the bee first visits a long-styled form of primrose the operation is reversed; it will then carry away pollen upon the tip of its proboscis and deposit this on the stigma of the next short-styled flower it visits.

123. In the common orchis the anther is placed above the stigma, which is a hollow viscid cavity in front of the flower, at the base of the lip, and the lip is produced into a long tube full of nectar. A bee seeking nectar thrusts its head against the anther, and in so doing detaches one or both of the two sticky glands to which two club-shaped masses of pollen are attached; these it carries away on its forehead, in an erect position. So long as the pollen masses are erect on the bee's head these do not reach the stigma of any other flower that it visits; gradually,

however, as the sticky gland contracts, the pollen masses incline forward and assume a horizontal position, in which they must touch the stigma of the next flower the bee visits, when the greater stickiness of the stigma detaches some or all the pollen from the bee's head and fertilizes the flower. Further, in some cases it takes so long for the pollen to assume the horizontal position, that by the time this has taken place the bee has visited all the flowers of the plant from which it took the pollen, and has gone to another plant.

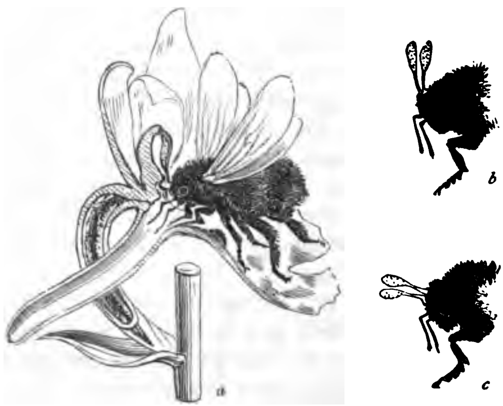

FIG. 57.—*a*, section of flower of orchis, showing a bee standing upon the lip with its head touching the sticky gland to which the pollen masses are attached; *b*, bee's head with the pollen masses erect, as removed; *c*, the same with the pollen masses after they have moved forwards—all enlarged.

124. Birds with long slender bills, as humming-birds, and also great moths, thus fertilize long-tubed flowers; in all which and many other cases the adjust-

ment of the parts of the flower to the form and habits of the insect or bird, and of these to the flower, is so accurate, that it is in vain to speculate whether the plant was adapted to feed the animal, or the animal adapted to fertilize the plant.

XXI.—THE FRUIT.

PERICARP, SEED.

125. The fruit consists of a covering (**seed-vessel**, or **pericarp**) containing one or more ripe seeds. The term should strictly apply to the result of the fertilization of one pistil, but it is extended to crowded masses of fruits belonging to several flowers on one peduncle or branch (mulberry, Fig. 58; fig, Fig. 59, pine-cone). These are called aggregate fruits, or infructescences, just as the aggregates of flowers are called inflorescences (Par. 75). Further, various organs of the flower or inflorescence, when retained on the fruit, are considered parts of the fruit; as the acorn-cup, which is formed of scale-like bracts (Par. 79); the flesh of the apple and pear which is the swollen peduncle. The strawberry (Fig. 64) consists of a fleshy receptacle covered with ripe carpels; and the hip of the rose (Fig. 31), is a hollow calyx-tube containing many ripe carpels.

126. The study of the fruit is more complicated than that of any other organ of the plant, because: 1. of its composition, which can only be made out by an examination of the pistil (Par. 109) in an earlier state: 2. because many parts visible in the pistil are often suppressed or masked in the fruit; 3. because

the seed is not always as distinguishable from the pericarp as the ovule is from the ovary; 4. because accessory organs are often attached to it or envelop it; 5. because carpels that are separate in the pistil may become combined in the fruit; 6. because the placentas (Par. 110) sometimes grow out and form additional partitions in the cavity of the fruit.

127. The simplest classification of fruits is into:— 1. **Pods**: these are dry, and their pericarp splits open along defined lines, or parts into separate pieces called **valves** (pea, Fig. 61, wallflower, Fig. 67); such are **dehiscent** fruits, their seeds fall out of the pericarp after it splits open. 2. Dry fruits that do not open by valves, and are hence called **indehiscent**; the seeds of such do not fall out but germinate within the pericarp, the embryo either throwing off the pericarp (maple), or its cotyledons remaining within it (acorn); of these there are two principal kinds, the **nut**, which is large and hard, and the **achene**, which is small, and usually has a thin pericarp. 3. Indehiscent fleshy fruits, that either rot on the ground and thus set the seeds free, or are eaten by birds which digest the flesh and reject the seeds (apple, holly, mistletoe, gooseberry). The chief kinds of these are the **berry**, which has a soft pericarp, and the **drupe**, of which the inner wall of the pericarp is hard and bony, or stony.

128. The above classification teaches nothing of the real nature of the fruit; the following does, and includes the chief kinds accessible to the student, who by examining them will obtain a better knowledge of fruits than by any other means. It is important to observe whether the fruit is the product of an inferior or superior ovary (Par. 84 *d*), and further, in the cases of fruits that are

composed of many combined dehiscent carpels, whether they split between the carpels (septicidal), or down the backs of these (loculicidal): or by the carpels separating from the placentas (septifragal, Fig. 67).

In the following enumeration the character of the seed is added to avoid subsequent repetition.

A.—Aggregate fruits or Infructescences (Par. 125).

Mulberry (Fig. 58).—A head of fruits, each consisting of a dry 1-seeded little indehiscent nut inclosed in four juicy perianth pieces.

FIG. 58.—Aggregate fruit of mulberry.

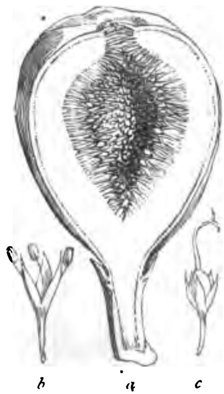

FIG. 59.—*a*, aggregate fruit of fig cut vertically; *b*, male, and *c*, female flowers, both much enlarged.

Fig (Fig. 59).—A hollowed-out fleshy peduncle, with bracts at the top, containing innumerable fruits, each consisting of a little 1-seeded indehiscent achene together with the remains of a perianth.

Pine-cone.—A series of woody scales, each with two seeds at its base (here there is no pericarp, see Par. 139).

B.—Simple fruits formed by the pistil of one flower.

(*a*) *Indehiscent fruits of one carpel.*

Plum, cherry.—Fruit (a drupe) superior; pericarp of an outer very fleshy, and inner stony coat. Seed solitary, without albumen.

Wheat (Fig. 12).—Fruit (an achene) superior; pericarp very thin, adhering so closely to the solitary seed that it cannot be separated. Seed albuminous. —In **oats** and **barley** the fruit is of the same structure, but inclosed in the hardened bracts (chaff).

Nettle (Fig. 60).—Fruit (an achene) minute, superior, flattened, dry, thin. Seed solitary, without albumen.

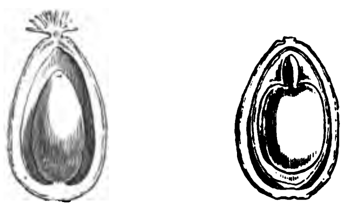

FIG. 60.—*a*, section of fruit of nettle much enlarged; *b*, section of seed of the same, showing the embryo, still more enlarged.

Barberry.—Fruit (a berry) superior; pericarp fleshy. Seeds 1 or 2, basal, albuminous.

Thistle (Fig. 42).—Fruit (an achene) crowned with a tuft of silky hairs (pappus, Par. 91). Seed 1, basal,

erect, without albumen.—In the **dandelion** (Fig. 41) the top of the fruit is drawn out into a long beak and crowned with a similar pappus. In the **daisy** the top of the fruit is obtuse and there is no pappus.

(*b*) *Dehiscent fruits of one carpel* (**pods**).

Pea (Fig. 61), **Bean.**—Fruit superior, dividing into 2 valves, with inner and outer line of dehiscence. Seeds many, without albumen, attached to the line

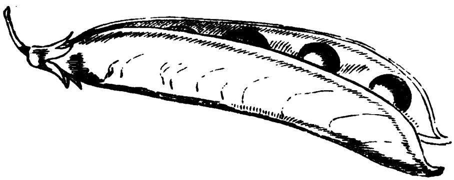

FIG. 61.—Fruit of pea splitting into two valves.

of dehiscence which is nearest to the separate stamen (Fig. 47).

(*c*) *Indehiscent fruits of several free carpels.*

Buttercup (Fig. 62).—Carpels many, dry (achenes), seated on a dry elevated receptacle. Seeds solitary in each achene, albuminous.

Bramble (Fig. 62), **Raspberry.**—Carpels many, fleshy (drupes), seated on an elevated receptacle. Seeds solitary, without albumen.

Strawberry (Fig. 64).—Carpels, many, dry (achenes), seated on a fleshy elevated receptacle. Seeds solitary, without albumen.

FIG. 62.—*a*, fruit of buttercup, cut open showing the seed; *b*, seed of the same cut open showing the small embryo within the albumen; both much enlarged.

FIG. 63.—Fruit of bramble with stamens and calyx beneath it.

FIG. 64.—Fruit of strawberry with calyx and bracts beneath it.

Rose (Fig. 31).—Carpels few or many, dry (achenes), seated within the hollowed-out fleshy top of the peduncle. Seeds solitary, without albumen.

(d) Indehiscent fruits of several combined carpels.

Ash.—Fruit superior, dry, winged (a winged achene commonly called a key), of two combined carpels, but 1-celled and 1-seeded by the suppression of one cell with its seed. Seeds solitary, albuminous.—The maple fruit is of the same nature, but each carpel has a wing, and the two separate when ripe; they do not, however, open so as to let the seed fall out.

Mallow (Fig. 65).—Fruit superior, a whorl of many 1-seeded carpels (achenes), combined by their sides. Seeds solitary in each carpel, albuminous.

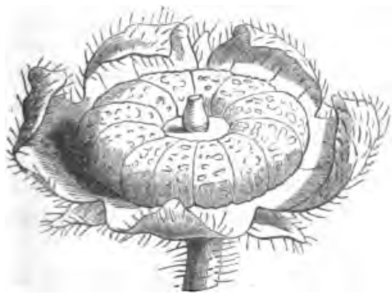

Fig. 65.—Fruit of mallow with calyx and bracts beneath it, enlarged.

Dead-nettle.—Fruit superior, of 4 dry lobes, each 1 seeded. Seeds albuminous.

Holly.—Fruit (a drupe) superior, fleshy, of 4 combined carpels, with four, 1-celled, 1-seeded stones. Seeds albuminous.

Olive.—Fruit (a drupe) superior, fleshy, of 2 combined carpels, forming a 2-celled stone; cells 1-seeded, one cell often wanting. Seeds albuminous.

Potato.—Fruit (a berry) superior, of 2 combined fleshy carpels, 2-celled, with many seeds in each cell. Seeds albuminous.

Apple (Fig. 66).—Fruit 5-celled, of five carpels enveloped in the fleshy swollen top of the peduncle, each with a horny inner coat, and 1 or 2 seeds. Seeds without albumen. This, the quince, pear, &c., are called pomes.

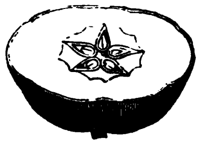

FIG. 66.—Fruit of apple cut across.

Gooseberry, Currant.—Fruit (a berry) inferior, of two combined fleshy carpels, 1-celled, with two parietal placentas, and several seeds immersed in pulp. Seeds albuminous.

Carrot, Parsnip.—Fruit inferior, of 2 combined dry carpels (achenes) that finally separate, each 1-seeded. Seeds albuminous.

Acorn.—Fruit (a nut) inferior, of 3 combined carpels, contained in a cup-shaped involucre (Par. 79); of these carpels one alone ripens, the others may be found as minute cavities at the base of the nut. Seed solitary, without albumen.—In the **beech** the fruit is of the same structure, but two fruits are together included in a woody, 4-valved involucre (Par. 79), and each nut is 3-angled.—The sweet chestnut has the same structure as the beech, but has three nuts in the involucre. (The horse-chestnut is altogether different, see further on.)

In the **hazelnut** the fruit is of the same structure, but the involucre, which is green and leathery, contains only one nut, whose pericarp is stony.

(e) Dehiscent fruits of several free carpels.

Columbine, Aconite, Larkspur.—Fruit superior, of 3 or more dry pods, splitting longitudinally down the inner face. Seeds numerous, albuminous.

(f) Dehiscent fruits of several combined carpels.

Willow.—Fruit superior, of 2 carpels, forming a 1-celled 2-valved pod. Seeds few, basal, without albumen, with long hairs at their bases.

Wallflower (Fig. 67).—Fruit superior, dry, of 2 carpels, forming a 2-celled pod, splitting from the

FIG. 67.—Pod of wallflower with one valve coming off.

base into 2 valves, which fall away from a framework. Seeds many, without albumen.

Violet (Fig. 53).—Fruit superior, dry, of 3 carpels, forming a 1-celled, 3-valved pod. Seeds many, albuminous.

Horse-Chestnut.—Fruit superior, of 3 carpels, forming a globose, leathery, prickly, 3-celled pod, opening to the base by 3 valves. Seeds one in each cell, without albumen; cotyledons combined into one mass.

Primrose, Cowslip.—Fruit (a pod) superior, dry, of 5 carpels forming a 1-celled pod, opening at the top by 5 valves. Seeds many, albuminous.

Heath.—Fruit superior, dry, of 5 carpels, forming a 5-celled pod, the carpels of which split longitudinally down the back. Seeds many, albuminous.

Rhododendron.—Similar to Heath, but with the carpels separating from one another and from the central axis, and opening longitudinally towards the axis.

Poppy.—Fruit superior, dry, of many carpels, forming a 1-celled pod, opening by small valves under the stigma. Seeds many, albuminous.

Iris, Crocus.—Fruit inferior, of 3 carpels, forming a 3-celled pod, the carpels of which split longitudinally down the back. Seeds many, albuminous.

Orchis.—Fruit inferior, dry, of 3 carpels, forming a 1-celled pod, with 3 valves, which often fall away from a persistent framework. Seeds many, without albumen.

129. The contrivances for the dispersion of fruits and for their becoming fixed to the ground, are very numerous, and afford most interesting studies. Many have winged appendages belonging to the carpels (maple, ash), or hooks by which they attach themselves to the fur of animals (cleavers), or wings formed

of accessory organs (bracts of lime), or hooks, or spines (involucres of beech, chestnut, burdock). Others have fine hairs (pappus), formed by the calyx (dandelion, thistle); others have a sticky surface, or one that gets sticky when the fruit falls on moist ground suitable for the germination of the seed (groundsel); whilst still others attract birds by their smell, colour, or sweetness, and are hence transported by them. Lastly, a few burst open with elastic force, scattering the seeds abroad (balsam).

XXII.—THE SEED.

TESTA, ALBUMEN, EMBRYO.

130. The seed consists of the **embryo** (Par. 35) and its coverings (**integuments**), and sometimes **albumen**; it is the ovule fertilized and arrived at maturity, at which period it has become independent of the parent plant; it is either sessile or attached to the pericarp by a short or long cord, **funicle** (Par. 110), through which it derived nourishment from the parent.

131. The **integuments** are usually double, the two coverings sometimes corresponding to the two coats of the ovule (Par. 114): the outer (**testa**) is generally the harder and thicker, and is sometimes, but very rarely, juicy (pomegranate and magnolia seeds). Two points should be carefully noted on the testa—the scar (**hilum**) indicating its point of attachment, and a minute hole (**micropyle**) by which the pollen tube entered the ovule (Par. 224). The radicle of the embryo almost always points to this hole. In some seeds a ridge (**raphe**) passes from

the funicle to the opposite end of the seed, indicating the position of the nourishing vessels that go to the base of the nucleus (Par. 114), where they sometimes expand into a dark spot. In many palm seeds the raphe sends branches of vascular bundles through the testa.

132. The **embryo** is a rudimentary plant (Par. 35) with partially-developed organs. The radicle of the embryo is developed first, and is hence to be found next the micropyle (Par. 131). When fully formed the embryo consists of a cotyledon or cotyledons, a plumule, and a radicle (Par. 36); of these parts each cotyledon represents a leaf, the plumule and radicle together form an axis, of which the first is the bud of a stem, the latter giving origin to the root. The plumule is, in many plants, not developed till after germination.

There are two principal kinds of embryo amongst flowering plants, the mono- and di-cotyledonous; both have cotyledon, plumule, and radicle, but they differ most materially in their structure and mode of growth (Par. 39).

133. The monocotyledonous embryo is often a cylindrical body, of which the upper part is the cotyledon, and usually presents a longitudinal slit or depression in which the plumule lies, the lower part is the short, blunt radicle. In germination the plumule ascends, developing alternate, often sheathing, leaves; whilst the radicle either elongates for a short time and is then replaced by adventitious roots, or is itself entirely undeveloped, but gives off sheathed adventitious roots (wheat, Fig. 12).

134. The dicotyledonous embryo is more compli-

cated; its two cotyledons are often relatively very large, they are usually equal and are always opposite, whilst the radicle is small and often short; in some plants, however, the radicle is larger than the cotyledons. The cotyledons may be thick (pea, Fig. 10; horse-chestnut, acorn), or thin (maple), flat (castor-oil), or folded (mallow, mustard, Fig. 11), or crumpled (convolvulus), veined with vascular bundles or not. The cotyledons may remain underground and suffer no change till they shrivel or decay (pea, bean, oak), or be carried up and become green leaves (mustard, Fig. 11) before the plumule is well developed. In germination the plumule ascends, rarely developing sheathing leaves, and the radicle elongates and branches.

135. The **albumen** consists of a mass of cells, containing starch, albuminoids (Pars. 17, 20), &c., provided for the nourishment of such embryos as possess it. It is formed always within the embryo-sac (Par. 116), and sometimes also in the tissue of the nucleus (Par. 114). Though all seeds do not contain albumen, this substance is found in more or less quantity in every embryo sac whilst the embryo is still young (see Fig. 55 *e*). There is no organic connection whatever between the mature embryo and the albumen with which it is in contact, but yet the embryo when germinating withdraws nourishing matter from the most distant part of the albumen (Par. 38).

136. Seeds, like fruits (Par. 129), are provided with various means for aiding their dispersion, in the shape of accessory growths, colour, juicy coverings, &c. Many have the testa produced into a thin wing (pine-seeds), or are covered with long hairs (cotton), or have a tuft of hairs at one end (willow-herb), or at the base (willow)

others become mucilaginous when moist, and thus adhere to the ground on alighting at a fit spot for growth (cress); or are supposed to attract birds by their brilliant colours, as certain tropical plants of the pea tribe, the pods of which open so as to expose the seeds; others have a juicy testa (pomegranate, magnolia, pæony); and still others, a fleshy cup or covering (an **aril**) formed by a growth from the funicle (Par. 130) (passion-flower and spindle-tree). The nutmeg-tree has a 1-seeded fruit like a peach, that splits open and exposes the nutmeg, surrounded by an aril of a brilliant scarlet colour; this aril (which is the mace) no doubt attracts pigeons, which swallow the nutmegs, and transport them from island to island of the Moluccas.

137. The vitality of seeds is very variable as to duration. Amongst instances of short-lived seeds are acorns, which germinate at once, and maple-seeds. As a proved instance of long-lived ones, the sacred bean of India is the most authentic; one such taken from a herbarium upwards of one hundred years old, having germinated. Wheat is said to keep for seven years at the longest. The statements as to mummy wheat are wholly devoid of authenticity; so are those as to the raspberry seeds taken from a Roman tomb. On the other hand that seeds may remain buried alive in the soil for many years is rendered most probable by the fact of charlock and broom appearing suddenly and in quanties in newly-turned up soil that had not been disturbed for long periods. It is, however, difficult to believe that such a moist complex substance as living protoplasm can resist chemical change sufficiently long to favour the idea that seeds have lain buried alive in the soil for many hundred years.

XXIII.—SURFACE COVERINGS AND APPENDAGES.

138. These are either exudations from the cells of the epidermis (Par. 6), or modifications of the epidermal cells, or cellular growths from them. They serve very various and totally distinct functions, all necessary to the health, growth, or propagation of the plant. The principal of them may be most instructively classed under their apparent uses to the plant:—

(*a*) **Protective.**—The simplest of all is the bloom of the grape, cabbage-leaf, pea-pod, &c. It consists of a secretion of wax (Par. 15), which being insoluble in water is probably intended to prevent its injurious effects on the subjacent tissues. Others are hairs and scales.

Hairs are produced by the outward growth of epidermal cells. They may either consist of single long cells (cotton) or strings of many cells (seen in the filaments of spider-wort). They are protections against wet, cold, and the effects of drought on the subjacent tissue. They are often branched (mallow) or radiate from a point like a star (winter-cress, arabis, alyssum); when the rays of such a star are combined in one plane, the result is a scale or scurf (elæagnus).

(*b*) **Defensive.**—The sting of the nettle is a single awl-shaped rigid cell, with a swollen base, in which an irritating fluid is secreted. On piercing the skin the point breaks off, and the fluid is deposited in the wound.

(*c*) **Attractive.**—Hairs that secrete a fluid (glands) which is resinous, sugary, or odorous, are very common

(sweet briar), and are perhaps intended to attract birds and insects for the purpose of fertilizing the flowers, or carrying off and thus dispersing the seeds.

(*d*) **Nutritive.**—The glandular hairs of the sundew, which both retain the insects that visit the leaves (thus acting also as **detentive** organs) and absorb nutriment from them. The sticky stems of the catchfly, and many other plants, probably serve the same purpose.

(*e*) **Scansorial** (aids to climb).—Such are especially prickles, which are hooked cellular growths from the epidermis. By their aid the bramble and many roses climb bushes, and so get to the light. By their aid also the rope-like rattan-canes of the Indies ascend the loftiest forest-trees, and expand their crown of foliage and flowers in the sun. They must not be confounded with spines (Par. 65).

XXIV.—GYMNOSPERMOUS PLANTS.

CONIFERS AND CYCADS.

139. There is a small but well-known group of flowering plants that differs so much from all others that it requires to be described separately. Its principal members are the **coniferæ**, plants which include pines, firs, larches, cedars, yews, cypresses, junipers, araucarias, the Wellingtonia, &c., and the **cycads**, palm-like plants of warm or hot countries. All are long-lived trees or shrubs, whose flowers have no perianth, and are almost invariably produced in male and female cones, consisting of scales, forming

close spirals round a woody axis. They are believed to have been inhabitants of the globe for a much longer period than any other flowering plants.

140. **Gymnosperms** resemble dicotyledons in the form and germination of the embryo, which however has often three or more cotyledons, in the exogenous growth of their stem (Par. 56), and they resemble all other flowering plants, in having stamens and ovules. They differ from dicotyledons in the layers of wood which are formed after the first year being destitute of vessels; in the universal presence of disks with central pores on the wood-tissue; and from all other flowering plants in the peculiar structure of the pollen, in the ovules not being inclosed in an ovary and being therefore fertilized by the direct contact of the pollen, and in the development of the embryo.

141. Their **stamens** for the most part consist of one or more anther-cells without filaments, situated on the under-surface of the scales of the male cone. Their **pollen** does not produce a tube from its inner membrane (Par. 108), but does so from a group of cells that form in its cavity.

142. Their **ovules** are borne on the upper surface of the scales of the female cone, each of which scales consists of an open carpellary leaf seated upon and combined with a bract (these are undistinguishable in the mature cone of the Scotch fir, but distinguishable in the larch). They resemble the ovules of flowering plants, and like them may have one or two coats, and be straight, or inverted through the greater growth of one side (Par. 115). The embryo-sac becomes filled with cellular tissue at an early period. Within this tissue

beneath the uppermost layer of cells forming the top of the sac, several larger cells appear, and form as many **secondary embryo-sacs.** At the same time, that one cell of the uppermost layer which lies immediately above each secondary sac, divides longitudinally into four, leaving a canal between them for the passage of the pollen tube.

143. **Fertilization** takes place by a pollen grain, carried by the wind, alighting on the top of the nucleus of the exposed ovule, and sending its tube through the cellular substance of the nucleus, down to the primary embryo-sac. There it reaches the passage between the four cells above a secondary sac, traverses it, and touches the latter. On this contact taking place the contents of the secondary sac are divided by a transverse partition into two portions, the lower of which subsequently again divides and forms four filaments that separate from one another and descend into the tissue of the primary sac and nucleus. In the nucleus each filament begins to form an embryo by cell-division at its extremity, but only one embryo usually arrives at maturity.

144. Thus in gymnosperms, instead of the nucleus of the ovule containing a simple embryo-sac with one germinal vesicle which gives origin to an embryo, several secondary sacs are formed within the primary one, of which each gives origin to four embryos; and as some gymnosperms have eight or more secondary embryo-sacs each producing four embryos, it follows that in such cases out of thirty-two or more commencements of embryos all but one are suppressed.

XXV.—CLASSIFICATION.

145. The objects of a **classification** of plants are, to place before the mind, in a clear manner, the relationships that exist between them, and to express these relationships in precise terms, so that they may be communicated orally or in writing, and thus facilitate and advance a knowledge of plants.

146. The idea carried out in all methods of classifying plants is derived from the fact, that they appear to be related to one another as are the members of the human race, lineally and collaterally; and whatever theory may be accepted for the origin of their kinds (**species**), the results obtained by classifying plants, and the mode of reasoning followed in detecting their relationships, are the same as what would obtain were they proved to have descended from one or more common ancestors.

147. For the purposes of classification a **nomenclature** is essential, and that nomenclature is the best which conveys briefly and in expressive terms some distinguishing attribute of the plant or group of plants to which its terms are applied. For this purpose the Latin and Greek languages are much used, because they are acquired by educated people in all civilized countries, and because they lend themselves by their flexibility and harmonious sounds to the compounding of names.

148. The names in constant use for the purpose of the classification of the members of the vegetable kingdom are individual, variety, species, genus, order, class, sub-kingdom. When referring to a plant, its generic and specific names are both used, puttin

the generic first if the Latin language is used, and the specific first if the English (as *Rosa canina*, dog-rose).

A **species** is an aggregate of individuals which have been proved to have descended from a common ancestor, or are so similar to one another that they may be presumed to have done so. But as no two individuals are exactly alike, and as the number of instances of unlikeness to the parent form increase with the number of individuals produced by seed, it becomes often difficult to define the limits of a species. These unlike individuals are called **varieties** (Par. 150); and the descendants of a well-marked variety that propagates its peculiarities with much constancy by seed is called a **race,** and sometimes a **sub-species.**

A **genus** is an assemblage of species resembling one another in most important points of structure, as the various kinds (species) of oak, elm, willow, &c.

Orders (also called **families**) are assemblages of genera agreeing in certain marked characters. These agreeing characters are sometimes obvious to the common observer, as those of the carrot and parsnip, which are two genera of one order; at other times they depend on characters of flower and fruit that are not recognized without botanical knowledge, as those of the buttercup and larkspur, which, though so unlike, are members of one order.

Classes are more comprehensive groups, as those of monocotyledon and dicotyledon. All classes are grouped under the two **sub-kingdoms** of flowering and flowerless plants which constitute the vegetable kingdom.

149. **Individuality.**—Plants, especially perennial ones, are often regarded as composite beings, or aggregates of individuals, because their buds may in the great majority of cases be detached and become separate individuals; because many parts annually die, and are replaced by similar parts; and because much of the substance of a tree or bush dies and remains as dead matter throughout the future life of the plant, forming a support as it were for the fresh buds developed from the living tissues that surround it. But whereas it is only of some plants that the buds are capable of becoming separate individuals, there are others of which single cells are capable of playing the same part; so that if the answer to the question of "What is an individual plant?" is to depend on this power of its parts to maintain a separate existence, it is a purely speculative one, and we are reduced to accept the only alternative of regarding each specimen as an individual, so long as it remains an organic whole.

150. **Origin of varieties.**—The result of cross-fertilization (Par. 119) is that the dissimilar qualities of two distinct individuals are combined in the embryo and appear in the future plant; whence it follows that the progeny of any individual plant which has been fertilized by another individual must differ more or less from that which bore it. Also seeds taken from different parts of the same plant being differently nourished will be likely to produce plants showing different amounts of unlikeness to the parent; and these sources of unlikeness are further affected by the conditions under which the seeds germinate and the future plant grows.

151. Profiting by these facts, gardeners highly manure certain plants, and cross-fertilize others, in order to obtain new races, often called strains; and by raising plants from all the seeds that ripen under these conditions they obtain a large choice of individuals differing in various degrees from their parents.

152. Nature proceeds more slowly: very few indeed of the seeds shed in a state of nature produce plants that arrive at maturity: most perish from falling on stony ground; or from drought; or are eaten by beasts, birds, or insects; or if they grow, the young plants are choked by surrounding plants, or eaten, or are otherwise killed. Of those that survive, such as resemble their parents in constitution will be the most numerous, and such will also most resemble their parents in outward character. Hence marked variations, though so easily produced in a garden, are comparatively rare in a state of nature.

153. **Origin of species.**—There are two methods of accounting for this; one, that of **independent creation**, that species were created under their present forms, singly or in pairs or in numbers: the other, that of **evolution**, that all are the descendants of one or a few originally created simpler forms. The first method is purely speculative, incapable from its very nature of proof; teaching nothing, and suggesting nothing, it is the despair of investigators and inquiring minds. The other, whether true wholly or in part only, is gaining adherents rapidly, because most of the phenomena of plant life may be explained by it; because it has taught much that is indisputably proved; because it has suggested multitude of prolific inquiries, and because it has

directed many investigators to the discovery of new facts in all departments of botany. It regards as proved—1. That the descendants of every plant depart (vary) more or less in character from its parents. 2. That of these variations some are better fitted than others, and even sometimes than their parent was, to survive in the area the plant inhabits. 3. That the conditions of the area are, like the individuals, variable. 4. That the number of deaths previous to maturity amongst the descendants is enormously greater than that of survivors, and that these deaths are due to the conditions of the area not having suited them. 5. That the descendants (variations) best fitted to thrive under the conditions of the area will be the survivors. 6. That these variations will hence ultimately in certain places supplant the parent form. 7. That the difference between a species and a variety being one of degree only, the variations accumulated through successive generations will become specific, and these again by a like process generic, and so on.

154. The great objection to the acceptation of this method of explaining the origin of species, is the difficulty of accounting for the apparent fixity of a species during even a limited period. This difficulty is met by the consideration that no individual which differs widely from its parental form (which has itself survived) can, as a rule, be suited to the conditions of the area it inhabits, and will consequently not increase and multiply; and that variation can have but narrow limits during any one or a few generations, just as the changes in natural conditions are slight during short periods.

155. **Hybrids** are the result of the ovules of one species having been fertilized by the pollen of another. They are called mules, and are rare in nature but easily produced by art. Many grow rapidly and flower copiously, but do not fertilize their ovules, owing to the imperfection of these or of their pollen; hence they rarely ripen seed. On the other hand, they often produce seed abundantly when fertilized by the pollen of one of their parents.

By hybridizing, many more valuable results in a horticultural point of view are produced than even by cross-fertilizing (Par. 151); a scentless species, if fertilized by the pollen of a scented one, may produce a scented hybrid; and by hybridizing, the qualities of size, form, and colour of flower, fruit, and leaf, hardiness, early or late flowering, &c., may be combined in plants whose parents each possessed one only of these qualities. It seems probable also that the hybridizing of distinct species, besides commingling their characters, adds greatly to the variability of their descendants.

XXVI.—PHYSIOLOGICAL EXPERIMENTS.

156. **Absorption and evaporation of water.**—Take up three plants of the buttercup carefully by the roots; leave one (No. 1) on the table; place another (No. 2) with its roots in water; hang the third (No. 3) upside down over a tumbler of water with a few of the leaves in the water, but the root exposed. In due time No. 1 will have faded; No. 2 will be quite fresh; No. 3 will have the parts not in the water faded. No. 1 shows that water contained in the plant has evaporated from its surfaces; No. 2

that the water has been absorbed by the root and conveyed to the leaves; No. 3 that the immersed leaves have not supplied the other portions of the plant with water.

157. **Evolution of oxygen by plants in sunlight.**—Take a bunch of fresh green leaves—water-

Fig. 68.

cresses answer well—and place them in a large bottle, then fill the bottle quite full of fresh spring water, so that no bubble of air is left in the bottle. Turn the mouth of the bottle, full of water and leaves, downwards into a basin full of water, and place the bottle and basin in the strong sunlight for an hour or two. If the leaves be then carefully examined they will be found to be covered with small bubbles, and that more of these bubbles have collected at the top of the bottle. These bubbles consist of pure oxygen gas derived from the carbonic acid contained dissolved in the spring water. This shows that plants have the power in presence of sunlight of decomposing carbonic acid, taking the carbon to build up their stems, leaves, &c., and setting free the oxygen as a gas. Now repeat the experiment; but instead of placing the bottle of spring water containing the

leaves in the light, put it in a dark cellar. There will then be no formation of bubbles of oxygen gas, even after standing for many hours. This shows that sunlight is necessary in order that green plants may decompose carbonic acid, and is therefore necessary for their growth.

158. **Respiration.**—In the green parts of plants the giving off of carbonic acid gas, which takes place in the respiration of all living things (Par. 23), is not observed (except in darkness) owing to the action of chlorophyll in decomposing carbonic acid. It becomes, however, very evident in parts which are not green.

Fill one-third of a wide-mouthed stoppered bottle of rather less than two quarts capacity with soaked peas, or with the expanding flower-heads of camomile or daisy. If the bottle is carefully opened after several hours the air contained will be found to extinguish a burning taper. This is due to the presence of carbonic acid gas.

By taking special precautions and using a very delicate thermometer, it is possible to show that a distinct rise of temperature takes place during the evolution of the carbonic acid. An illustration on a large scale of this rise of temperature is afforded by barley during the process of malting.

159. **Transpiration.**—Cut two branches of the same plant. Put one in a warm, the other in a cool place. Note that the former fades soonest. With a sufficiently delicate pair of scales this may be shown to arise from a larger loss of water. Transpiration proceeds more rapidly in warm air than in cold, because the former is able to hold a larger amount of moisture.

160. **Germination.**—Suspend an acorn or horse-chestnut by a piece of twine in the neck of a wide-mouthed bottle, and above the surface of some water. Place the bottle in a warm place. The water will evaporate and moisten the suspended seed, which will germinate. The condensed water is necessarily pure, and it is evident that this is the only material required by seeds in order to germinate.

Repeat the experiment with two sets of bottles; place some in a warm, others in a cooler place. Compare the time in which germination is effected.

161. **Effect of light on chlorophyll.**—Sow some cress seed, and keep the pots in a dark place. The seed-leaves will be pale. Remove part of the germinating plants to the light; the seed-leaves will become green. Compare their progress in this respect with those kept in the dark.

Press closely upon the surface of a geranium leaf some pieces of tin-foil, and afterwards expose the leaf for five to ten minutes to bright sunlight. The parts covered with the tin-foil will be found to have a darker colour than the rest. The lighter tint is due to the movement of the chlorophyll granules under the influence of light from the upper and lower surfaces of the cells to their sides.

162. **Colour of flowers independent of light.**—Grow hyacinths of different colours in a completely dark cellar. They will expand their leaves and flowers. The former will be pale, but the latter will develop their proper colours.

163. **Heliotropism.**—Place a pot of germinating cress before a window. It will be found after a f[illegible] days that the stems are turned in the direction of

light. This is due to the fact that light retards growth, and therefore the sides of the stem turned to the light and away from it come to have different lengths, and the stem consequently bends.

It follows from this that if a pot of germinating cress be shaded equally all round, the plants will grow faster than if not so shaded.

Grow some germinating cress in a closed box in one side of which a piece of dark red glass has been introduced; there will be no curvature in the growth. Repeat the experiment, substituting a piece of deep blue glass; curvature will take place as with ordinary daylight. This proves that the heliotropic effect of light is due to the rays belonging to the violet end of the spectrum.

XXVII.—INSTRUCTIONS FOR TEACHERS OF ELEMENTARY BOTANY.

When practicable, let the pupils themselves be employed under the teacher's eye in gathering the plants required for the day's lesson. This is a very important matter, not only because the pupils will be more interested in the examination of plants which they have themselves gathered, and of which they hence know something by sight, but will remember better what they have been taught about them. In doing this, they should be practised in selecting and taking up good specimens—by the root when the whole plant is to be studied—and to select and cut (not tear off) similar branches, leaves, or flowers, when such portions only of the plant are required. It is most essential that every pupil be supplied with a specimen which shows -arly everything the teacher has to demonstrate.

The pupils should be instructed to handle specimens without bruising them—to inspect every organ or assemblage of organs (as the flower) before removing it, and to remove its parts methodically and neatly. They should further be practised in making sections of flowers, to show the superposition of the floral whorls, and transverse ones of buds, to show the overlapping (æstivation) of the whorls. Similar sections should be made of leaf-buds, stems, fruits, &c.

The use of the pocket-lens should be carefully practised; one magnifying three or four times will suffice for most purposes; it should be held steadily in front of the eye-ball, and the specimen be brought to it, not holding the lens in front of the specimen, and then viewing it from a distance (as is invariably the case with beginners).

It is impossible to exaggerate the importance of the above simple directions in the art of manipulation, which facilitate progress in a remarkable degree. It is a common thing to find at the end of a course that some pupils have learnt nothing—not from want of ability or attention, but because they were not supplied with good specimens, or had spoiled these in fruitless attempts to follow the teacher with knife, forceps, and lens, their attention having been distracted by their own failures from his demonstrations.

With regard to botanical lessons, they must be realities, and be given with the same regularity, method, and strictness of discipline, as any other school lessons. It is a mistake to suppose that learning botany has any great attraction for the young, or that its attainment requires less application than oth

studies. The progress which the pupil will make in it will be in proportion to (1) his studiousness, (2) his powers of observation, (3) his thirst for knowledge, heightened by a love of plants, which latter is the rarest qualification of the three. The utmost the teacher can expect is, to find the lessons in botany less forbidding than most others, and this because the pupil's hands and eyes being occupied along with his brains, his attention is kept up with less effort.

Again, the best effect of the use of this Primer is not to be sought in the amount of botany learnt thereby, but in the training in the habits of observation and reflection as applied to natural objects that it affords—a training otherwise wanting in school education, and rarely subsequently obtained except in the case of a medical one. For this training botany is eminently adapted, because of the facility with which plants can be obtained, and their parts be detached and studied, and because of the definiteness of the terms employed in designating these parts and their characters. I feel assured that the pupil may well afford to forget all the botany this little book teaches, provided only he retains those habits which it inculcates, of observing accurately, reasoning intelligently, and describing what he has seen more methodically, accurately, and concisely, than he would otherwise have done.

I have been asked to append a series of questions to this Primer, but do not do so, because such questions tend to limit the views of teachers and the aims of pupils. For the teachers I regard them as particularly hurtful, as absolving them from the necessity of thinking for themselves. No practice in a subject is

so good as that of propounding questions on it; and the value of answers given to well-chosen questions is best estimated by those who devise the latter. Furthermore, in the natural-history sciences, the examinations should, like the lessons, as far as possible, be on specimens.

XXVIII.—A SCHOOL GARDEN OF FLOWERING PLANTS.

The following is a list of such easily procured and easily cultivated plants as will afford the teacher ample materials for instruction in Elementary Botany, will give an idea of the natural arrangements of flowering plants, and will convey a practical knowledge of many useful vegetables cultivated in all temperate regions.

This list is capable of indefinite extension according to the knowledge of the teacher, the size of the garden the nature of its soils, the means at hand of procuring roots or seeds, and the labour that can be obtained for cultivating them. Abundant specimens of eacl should be grown, so that every pupil may have plent) to cut up and examine with the teacher.

The trees and shrubs marked with an asterisk (*) cannot well be introduced into such a garden amongst the herbaceous plants, but their names should be introduced in their proper places, and the pupil's attention should be directed to the plants themselves in neighbouring woods and plantations.

SERIES I.—**Angiosperms.** Flowering plants having the ovules inclosed in an ovary. Woody tissue containir abundant vessels.

CLASS I.—DICOTYLEDONS.

DIVISION I. THALAMIFLORAL.—Flowers usually with both a calyx and a corolla—the latter of separate petals. Stamens inserted close under the ovary (not on the calyx). Ovary always superior.

Order *Ranunculaceæ.*—Clematis, anemone, buttercup, hellebore, ficaria, columbine, larkspur, aconite, pæony.
Order *Berberideæ.*—Barberry.
Order *Papaveraceæ.*—Poppy, greater celandine.
Order *Fumariaceæ.*—Fumitory.
Order *Cruciferæ.*—Stock, wallflower, arabis, cabbage, shepherd's purse, honesty, mustard, cress, candy-tuft, sea-kale, radish, charlock, turnip.
Order *Resedaceæ.*—Mignonette.
Order *Cistineæ.*—Rock-rose, gum cistus.
Order *Violaceæ.*—Heartsease, dog-violet.
Order *Caryophylleæ.*—Pink, sweet-william, catchfly, stitchwort, spurrey, chickweed.
Order *Hypericineæ.*—Tutsan, St. John's-wort.
Order *Malvaceæ.*—Marshmallow, lavatera, common mallow.
*Order *Tiliaceæ.*—Lime.
Order *Lineæ.*—Flax.
Order *Geraniaceæ.*—Crane's-bill, stork's-bill, pelargonium, tropæolum, balsam.
Order *Ampelideæ.*—Grape-vine, Virginia-creeper.
*Order *Ilicineæ.*—Holly.

DIVISION II. CALYCIFLORAL.—Characters of Division I., but stamens inserted upon the calyx, and ovary either inferior or superior.

*Order *Sapindaceæ.*—Maple, horse-chestnut.
*Order *Celastrineæ.*—Spindle-tree.
*Order *Rhamneæ.*—Buckthorn.
Order *Leguminosæ.*—Furze, broom, *laburnum, clover, lucerne, saintfoin, pea, bean, vetch.
Order *Rosaceæ.*—*Plum, *cherry, spiræa, bramble, raspberry, strawberry, cinquefoil, dog-rose, sweetbriar, *pear, *apple, *hawthorn.
Order *Saxifrageæ.*—London pride, gooseberry, currant.
Order *Droseraceæ.*—Sundew.
Order *Crassulaceæ.*—Orpine, stone-crop, house-leek.

Order *Onagrarieæ.*—Willow-herb, evening primrose, enchanter's night-shade.
Order *Lythraceæ.*—Loose-strife.
Order *Cucurbitaceæ.*—Bryony, gourd.
Order *Umbelliferæ.* — Pennywort, hemlock, celery, caraway, chervil, fennel, parsley, coriander, fools'-parsley, carrot, parsnip, cow-parsnip.
Order *Araliaceæ.*—Ivy.
Order *Cornaceæ.*—Cornel.

DIVISION III. COROLLIFLORAL.—Flowers with both calyx and corolla, the latter usually of combined pieces. Stamens usually inserted upon the corolla.

SUB-DIVISION 1.—Ovary inferior.

Order *Caprifoliaceæ.*—Guelder-rose, elder, honeysuckle, laurustinus.
Order *Rubiaceæ.*—Madder, bedstraw, cleavers, woodruffe.
Order *Valerianeæ.*—Valerian, corn-salad.
Order *Dipsaceæ.*—Teazle, scabious.
Order *Compositæ.*—Cornflower, thistle, burdock, butter-bur, coltsfoot, single aster, daisy, golden rod, sunflower, chamomile, milfoil, corn marigold, tansy, wormwood, groundsel, chicory, goatsbeard, lettuce, dandelion, sow-thistle, hawkweed.
Order *Campanulaceæ.*—Lobelia, rampion, campanula.
Order *Vaccinieæ.*—Bilberry.

SUB-DIVISION 2.—Ovary superior.

Order *Ericaceæ.*—Arbutus, heath, ling, rhododendron.
Order *Oleineæ.*—Privet, *ash, lilac, jasmine.
Order *Apocyneæ.*—Periwinkle.
Order *Gentianeæ.*—Centaury, gentian.
Order *Polemoniaceæ.*—Jacob's ladder, phlox.
Order *Convolvulaceæ.*—Convolvulus, dodder.
Order *Boragineæ.*—Bugloss, borage, comfrey, lungwort, forget-me-not.
Order *Solaneæ.*—Henbane, nightshade, potato, deadly nightshade, tobacco, thorn-apple.
Order *Plantagineæ.*—Plantain.
Order *Scrophularineæ.*—Mullein, toad-flax, snapdragon, mimulus, foxglove, speedwell, yellow rattle.
Order *Labiatæ.*—Mint, marjoram, thyme, balm, sage, prunella, horehound, dead-nettle, rosemary.
Order *Verbenaceæ.*—Vervain.
Order *Primulaceæ.*—Primrose, cowslip, lysimachia, pimpernel
Order *Plumbagineæ.*—Thrift, sea lavender.

DIVISION IV. INCOMPLETE.—Flowers with a single perianth or none.

SUB-DIVISION 1.—Flower with a single perianth.

Order *Polygoneæ.*—Bistort, buckwheat, dock, rhubarb.
Order *Chenopodiaceæ.*—Beet, spinach, goosefoot, orache.
Order *Thymeleæ.*—Daphne.
Order *Elæagneæ.*—Sea buckthorn.
Order *Aristolochieæ.*—Asarabacca, birthwort.
Order *Euphorbiaceæ.*—Spurge, castor oil, dog's mercury, box.
Order *Urticeæ.*—Nettle, pellitory, *fig, *mulberry.
Order *Cannabineæ.*—Hop, hemp.
*Order *Ulmaceæ.*—Elm.
*Order *Cupuliferæ.*—Oak, beech, hazel, hornbeam, chestnut.

SUB-DIVISION 2.—Flowers without obvious perianth.

*Order *Betulaceæ.*—Birch, alder.
*Order *Salicineæ.*—Poplar, willow.

CLASS II.—MONOCOTYLEDONS.

DIVISION I.—Flowers with a distinct perianth.

SUB-DIVISION 1.—Perianth superior.

Order *Orchideæ.*—Orchis, helleborine, listera
Order *Irideæ.*—Crocus, iris, gladiolus.
Order *Amaryllideæ.*—Narcissus, snowdrop.
Order *Dioscoreæ.*—Black bryony.

SUB-DIVISION 2.—Perianth inferior.

Order *Alismaceæ.*—Water plantain, flowering rush.
Order *Liliaceæ.*—Asparagus, butcher's broom, lily of the valley, Solomon's seal, squill, star of Bethlehem, onion, fritillary, tiger-lily, tulip, colchicum, crown imperial, hyacinth.
Order *Junceæ.*—Rush, wood-rush.

DIVISION II.—Flowers without a distinct perianth.

Order *Aroideæ.*—Arum.
Order *Typhaceæ.*—Bur-reed, reed-mace.
Order *Cyperaceæ.*—Bulrush, cotton grass, galingale, sedge.
Order *Gramineæ.*—Foxtail grass, canary grass, vernal grass, bent grass, millet grass, oat, reed, cocksfoot grass, couch grass, meadow grass, quaking grass, fescue grass, broom grass, wheat, barley, rye.

SERIES II.—**Gymnosperms.** Flowering plants with the ovules naked. Woody tissue destitute of vessels (except that of first year).

Order *Coniferæ.*—Juniper, *pine, Irish yew, cypress, arbor-vitæ, *cedar, *larch, *spruce.

XXIX.—SCHEDULES FOR EXERCISES ON LEAVES AND FLOWERS.

The first of these schedules is similar to that devised by the late Professor Henslow of Cambridge as a means of training the children of a village school in habits of accurate observation, by examining the structure of flowers. I have added one for leaves, which is even simpler and quite as useful for beginners; it is adapted for trees and shrubs, but may be extended and modified so as to embrace herbs, in which the stem- and root-leaves often differ in shape.

Blank schedules should be kept in great numbers and freely used by the pupils.

NAME OF PUPIL.	FLORAL SCHEDULE BUTTERCUP.		DATE AND PLACE WHERE GATHERED.	
Organ	*No.*	*Whether separate or combined*	*Whether superior or inferior*	*Remarks*
Calyx Sepals	5	separate	inferior	green, hairy
Corolla Petals	5	separate	inferior	yellow, shining
Stamens	many	separate	inferior	crowded, with filaments
Pistil Carpels	many	separate	superior on an elevated receptacle	crowded, in a round head, style o
Ovules or seeds in each carpel	1	At the base of the cavity		

Name of Pupil.		Leaf Schedule.			Date.		
Leaf of	*lime*	*horse chestnut*	*soft grass*	*ash*	*oak*	*ivy*	*pear*
Position and Stipulation	alternate stipulate	opposite exstipulate	alternate exstipulate	opposite exstipu ate	alternate stipulate	alternate exstipulate	alternate stipulate
Insertion	petioled	petioled	sessile on a sheath	petioled	petiole short or none	petioled	petioled
Division	simple	into seven leaflets	simple	pinnate	simple	simple	simple
Margins	serrate	serrate	entire	serrate	lobed	lobed	serrate
Surface	glabrous	glabrous	downy	glabrous	glabrous	glabrous	downy
Veins	branching from a midrib	branching from a midrib	parallel through length of leaf	branching from a midrib	branching from a midrib	spreading from top of petiole	branching from a midrib

XXX.—INDEX OF PLANTS REFERRED TO.

(*Under their Paragraphs*).

The plants referred to in this Primer are, with few exceptions, easily procured, either from woods, fields, or shrubberies, or from gardens; they should be used in a fresh state when possible, though many may be dried flat between paper so as to show their instructive parts. Some, as wheat-ears, acorns, peas, &c., should be kept dry in quantities to be used for exercises; others, as strawberries and such soft fruits, may be preserved in alcohol diluted with water. Lastly, a few objects must be had of a dealer who prepares slices of wood, starch grains, &c., for the microscope—these are marked with an asterisk (*).

THE END.

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